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EDITORIAL

FUTUROS DA ÁGUA-RESILIÊNCIA, GOVERNAÇÃO E ADAPTAÇÃO

Simbolicamente a água foi, ao longo dos séculos, fonte de vida, de purificação e de regeneração, consubstanciando: "(…) l'infinité des possibles, elles [as águas] contiennent tout le virtuel, l'informel, le germe des germes, toutes les promesses de développement, mais aussi toutes les menaces de résorption." (Chevalier, Gheerbrant, 1969, p.374). Contudo, para além da perceção, representação e interpretação *ontológica,* a água é um recurso natural finito, insubstituível, essencial à vida. Daí a necessidade de garantir a sustentabilidade hídrica, amiúde ameaçada, seja por ação de fenómenos naturais seja por ação humana: "La nature change à toute vitesse, mais nos manières de penser ce changement héritent d'un long passé, de luttes et de savoirs(…)" (Fressoz, Locher, 2020, p. 317)

É por estas razões que o segundo número da Revista AD ASTRA reflete sobre possíveis **Futuros da Água-Resiliência, Governação e Adaptação.** Cumprimos, deste modo, aquele que é um dos nossos primeiros desígnios, o de disseminar a investigação produzida no seio da Universidade Aberta, num espaço de reflexão plural e transdisciplinar, de intensa e profícua partilha do conhecimento, participando ativamente no pensar o mundo e nas possíveis formas de o transformar, construindo um futuro melhor.

Prosseguindo um intenso trabalho colaborativo e participativo, o nosso dossier temático congrega, pela mão de Jorge Trindade, trabalhos que foram apresentados e debatidos no Seminário Internacional *Water, Sustainability and Development'25*, que teve lugar a 9 de maio de 2025 na *Polydisciplinary Faculty of Safi,* da *Cadi Ayyad University,* em Marrocos. Assim se reflete e procura dar resposta aos desafios que as sociedades contemporâneas vivem, nomeadamente no que a este nosso bem essencial diz respeito. Para além das questões em torno da disponibilidade, abastecimento e reutilização da água analisam-se os desafios suscitados pelas profundas e aceleradas alterações climáticas, pelas assimetrias sociais e económicas, procurando propostas que não se confinem à dimensão técnica e que incorporem possíveis intervenções sociais, territoriais, institucionais e culturais.

Mas para além desta intensa reflexão e sob a reminiscência da *Harmonie hydro-végétale et météorologique* de François-Antoine Rauch (1802), a secção *Varia* abre com um ensaio sobre as grandes florestas tropicais na região dos Grandes Lagos e sobre a segurança ambiental. De seguida, analisam-se as impressões de uma viagem ao Egipto, narrada logo nos inícios do século XX, pelo engenheiro e escritor José de Souza Larcher. Como prelúdio de novas leituras fecha-se esta secção meditando-se sobre os vinte anos da Convenção Faro, e do valor do Património Cultural na Sociedade Contemporânea.

Por último, e na nossa secção testemunho(s) evoca-se a figura do primeiro reitor da Universidade Aberta, através da criação e atribuição do Prémio Armando Rocha Trindade.

Assim, preservando-se no presente a memória do nosso passado recente, apontamos, por entre outras desafiantes leituras, aqueles que são os possíveis e resilientes futuros de um dos nossos maiores bens: a **Água**.

Ana Paula Avelar
Fevereiro de 2026

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Resumo

A água é um recurso natural finito, insubstituível, essencial à vida, pelo que o dossier temático do segundo número da Revista AD ASTRA reflete sobre possíveis **Futuros da Água-Resiliência, Governação e Adaptação**. Mas, para além desta problemática e na secção *Varia,* revisitam-se as profundas transformações vividas nas florestas tropicais na região dos Grandes Lagos, transitando-se para as impressões de uma viagem ao Egipto nos inícios do século XX e meditando-se sobre os vinte anos da Convenção Faro e a importância do Património Cultural. Para além do convite à leitura de dois livros, no espaço testemunho(s) evoca-se a figura do primeiro reitor da Universidade Aberta, através da recente criação Prémio Armando Rocha Trindade.

Palavras-Chave: Água, Governação, Florestas Tropicais; Egipto; Património Cultural.

Abstract

Water is a natural resource that is both finite and irreplaceable, essential to life, with this in mind the second issue of AD ASTRA journal reflects on Future Water-Resilience, Governance and Adaptation. Furthermore, in addition to this topic, the Varia section revisits the profound transformations experienced in the tropical forests of the Great Lakes region, shifting to impressions of a trip to Egypt in the early 20th century and pondering the twenty years of the Faro Convention and the relevance of Cultural Heritage. As well as inviting readers to explore two books, the Testimony(ies) section evokes the figure of the first rector of the Aberta University through the recently created Armando Rocha Trindade Award.

Keywords: Water, Governance, Tropical Forests; Egypt; Cultural Heritage

DOSSIER TEMÁTICO

O FUTURO DA ÁGUA

RESILIÊNCIA, GOVERNAÇÃO E ADAPTAÇÃO

Futuros da Água: Resiliência, Políticas de Governação e Adaptação Local – Apresentação

Water Futures: Resilience, Governance, and Community Adaptation – Presentation

Jorge Trindade

Os trabalhos reunidos neste dossiê temático resultam do Seminário Internacional Water, Sustainability and Development '25 (https://sites.uab.pt/wsd25/), realizado a 9 de maio de 2025 na Polydisciplinary Faculty of Safi, da Cadi Ayyad University, em Safi, Marrocos. Este encontro científico constituiu um espaço privilegiado de diálogo interdisciplinar, reunindo investigadores, estudantes e representantes de instituições locais e nacionais, com o objetivo de promover uma reflexão crítica e integrada sobre os desafios contemporâneos associados à água, enquanto recurso essencial, bem comum e eixo estruturante do desenvolvimento sustentável.

O seminário teve como principal objetivo afirmar-se como um fórum de discussão entre diferentes comunidades científicas e profissionais. Grande parte do debate de ideias centrou-se nas problemáticas da disponibilidade, abastecimento e reutilização da água, bem como nos riscos associados e nas capacidades das comunidades locais para lidar com este desafio global.

Jorge Trindade
Centre for Functional Ecology - Science for People & the Planet (CFE), Universidade de Coimbra, Coimbra, Portugal
Universidade Aberta, Lisbon, Portugal
0000-0001-5610-5942

Este desafio surge num contexto marcado pelas alterações climáticas, pelo aumento das desigualdades sociais e pela intensificação dos processos de urbanização. Consequentemente, o debate em torno da sustentabilidade da água assume uma relevância crescente, exigindo abordagens que ultrapassem soluções meramente técnicas e integrem dimensões sociais, territoriais, institucionais e culturais.

Os 24 artigos que compõem este dossiê refletem essa diversidade de perspetivas e enquadram-se em três grandes áreas temáticas que estruturaram o seminário e também este dossiê. A primeira, riscos relacionados com a água, alterações climáticas e desafios societais, reúne contributos centrados na análise dos riscos hidrológicos, na sua intensificação em resultado das alterações climáticas e nas implicações sociais e territoriais desses processos. A segunda área, sustentabilidade ambiental dos recursos hídricos, foca-se na avaliação, conservação e uso sustentável dos sistemas ambientais que sustentam os recursos hídricos, destacando a necessidade de abordagens integradas e de longo prazo. A terceira, Governação da água e inclusão social, explora as dimensões institucionais, sociais e culturais da governação da água, com especial atenção à equidade, à participação e à inclusão social.

Em conjunto, estes trabalhos evidenciam a centralidade da água como elemento estruturante das relações entre ambiente, sociedade e desenvolvimento, sublinhando a complexidade dos desafios atuais e a necessidade de respostas articuladas

entre diferentes escalas e setores. Os contributos apresentados demonstram que a sustentabilidade hídrica não pode ser dissociada das dinâmicas territoriais, das formas de governação e das capacidades adaptativas das comunidades, particularmente em contextos marcados por vulnerabilidades socioambientais.

Este dossiê temático reúne investigadores provenientes de diversas instituições de Portugal, Brasil, Marrocos e Moçambique, refletindo a vocação internacional e colaborativa do WSD'25. A diversidade geográfica e institucional dos autores contribui para uma leitura plural dos problemas analisados e reforça o valor da comparação entre contextos diferenciados, enriquecendo o debate científico e ampliando o potencial de transferência de conhecimento entre regiões com desafios comuns, ainda que expressos de formas distintas.

Por fim, este conjunto de artigos constitui também um testemunho da importância das parcerias académicas e da cooperação internacional na produção de conhecimento relevante e socialmente comprometido. O WSD'25 e o presente dossiê demonstram que o avanço científico em torno da água, da sustentabilidade e do desenvolvimento depende de espaços de diálogo inclusivos, multidisciplinares e interculturais. Espera-se que os contributos aqui reunidos não apenas aprofundem o debate académico, mas também inspirem novas colaborações, projetos conjuntos e um compromisso renovado com a construção de sociedades mais resilientes e sustentáveis face aos desafios hídricos do século XXI.

The works brought together in this thematic dossier stem from the International Seminar Water, Sustainability and Development '25 (https://sites.uab.pt/wsd25/), held on 9 May 2025 at the Polydisciplinary Faculty of Safi, Cadi Ayyad University, in Safi, Morocco. This scientific meeting constituted a privileged space for interdisciplinary dialogue, bringing together researchers, students, and representatives of local and national institutions, with the aim of promoting a critical and integrated reflection on contemporary challenges related to water as an essential resource, a common good, and a structuring axis of sustainable development.

The seminar's main objective was to establish itself as a forum for discussion among different scientific and professional communities. Much of the debate focused on issues of water availability, supply, and reuse, as well as associated risks and the capacities of local communities to address this global challenge. This challenge emerges in a context marked by climate change, increasing social inequalities, and the intensification of urbanization processes. Consequently, the debate on water sustainability is gaining increasing relevance, requiring approaches that go beyond purely technical solutions and integrate social, territorial, institutional, and cultural dimensions.

The 24 articles that make up this dossier reflect this diversity of perspectives and are framed within three major thematic areas that structured both the seminar and this dossier. The first, water-related risks, climate change, and societal challenges, brings together contributions focused on the analysis of hydrological risks, their intensification as a result of climate change, and the social and territorial implications of these processes. The second area, environmental sustainability of water resources, focuses on the assessment, conservation, and sustainable use of environmental systems that support water resources, highlighting the need for integrated and long-term approaches. The third, water governance and social inclusion, explores the institutional, social, and cultural dimensions of water governance, with particular attention to equity, participation, and social inclusion.

Taken together, these works highlight the centrality of water as a structuring element in the relationships between environment, society, and development, underscoring the complexity of current challenges and the need for coordinated responses across different scales and sectors. The contributions presented demonstrate that water sustainability cannot be dissociated from territorial dynamics, forms of governance, and the adaptive capacities of communities, particularly in contexts marked by socio-environmental vulnerabilities.

This thematic dossier brings together researchers from various institutions in Portugal, Brazil, Morocco, and Mozambique, reflecting the international and collaborative vocation of WSD'25. The geographical and institutional diversity of the authors contributes to a plural reading of the issues analyzed and reinforces the value of comparison between different contexts, enriching the scientific debate and expanding the potential for knowledge transfer between regions facing common challenges, even if expressed in different ways.

Finally, this collection of articles also stands as a testament to the importance of academic partnerships and international cooperation in the production of relevant and socially engaged knowledge. WSD'25 and this dossier demonstrate that scientific progress on water, sustainability, and development depends on inclusive, multidisciplinary, and intercultural spaces for dialogue. It is hoped that the contributions gathered here will not only deepen academic debate but also inspire new collaborations, joint projects, and a renewed commitment to building more resilient and sustainable societies in the face of the water challenges of the 21st century.

Água e desenvolvimento: a importância das perceções sociais em Marrocos

Water and development: the importance of social perceptions in Morocco

Carla Fernandes
Fátima Alves

Resumo

Marrocos enfrenta uma disponibilidade de água per capita em declínio, com consequências negativas para a agricultura, a segurança alimentar e energética, a estabilidade social e a própria sustentabilidade do seu modelo de desenvolvimento. Este artigo analisa criticamente a gestão da água em contextos rurais e urbanos, abordando os impactos socioeconómicos e as respostas comunitárias. Salienta a importância de analisar as perceções e práticas locais de uso da água, valorizando o conhecimento continuamente produzido pelas comunidades, que pode, assim, complementar as estratégias institucionais de produção e distribuição de água. No Antropoceno, é essencial desenvolver soluções que respondam eficazmente e de forma sustentável às diversas realidades territoriais de Marrocos.

Palavras-Chave: Recursos Hídricos; Perceções Locais; Desenvolvimento Sustentável; Marrocos.

Abstract

Morocco faces declining water availability per capita, which threatens its agriculture, food, and energy security, as well as social stability and the sustainability of its development model. This article critically examines water management in rural and urban settings, addressing both socio-economic impacts and community responses. It emphasises the importance of engaging with local perceptions and practices of water use, highlighting the adaptive knowledge continuously generated by communities. Such insights can complement institutional strategies for water production and distribution. In the Anthropocene, locally led and context-sensitive approaches are essential for designing sustainable development solutions that effectively respond to Morocco's diverse and evolving territorial realities.

Keywords: Water Governance; Local Perceptions; Sustainable Development; Morocco.

Carla Fernandes
Fátima Alves
Centre for Functional Ecology-Science for People & the Planet, Department of Life Sciences, Faculty of Sciences and Technology, TERRA Laboratory, University of Coimbra, Coimbra, Portugal
Department of Social Sciences and Management, Universidade Aberta, Lisbon, Portugal

0000-0002-2650-9759
0000-0003-2600-8652

Introduction

While the world is pushing all the planet's ecological boundaries (Richardson et al., 2023), Morocco faces serious concerns related to water scarcity (World Bank, 2022). Water scarcity is particularly critical since agriculture constitutes a large percentage of the Moroccan economy (Van Praag & Ou-Salah, 2021), and it is necessary for vital sectors such as food and energy production (Figure 1). Furthermore, water-related concerns could increase local tensions (IEP, 2024).

This study aims to present a reflection on specific water management issues and their consequences in rural and urban areas in Morocco. It is followed by a broader reflection on sustainability and development, seeking to draw light into the importance of understanding context-centred local perceptions regarding the management of resources.

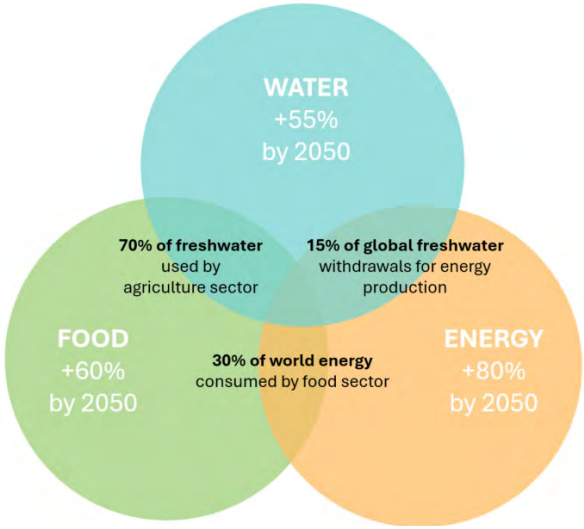

Figure 1. Interconnected water, energy, and food security challenges (Daher & Mohtar, 2021).

Water Management in rural areas

Water scarcity results from declining precipitation and overexploitation of groundwater resources (El Asri et al., 2022). Other factors, such as the increasing salinity in groundwater in coastal areas due to sea-level rise, can also endanger available freshwater (Rayan et al., 2022).

Agricultural practices are also changing with the introduction of new economic actors and legislation. In practice, shifts in the agricultural sector's economic paradigms, with larger and more transient companies requiring daily labourers, are replacing the family-centred farm economic model in rural areas (Ameur et al., 2017). Measures relying on limitations on farming products that depend extensively on water are being implemented in different areas. This is leading to the displacement of large companies to other areas with different rules, leaving behind depleted groundwater resources and daily workers without income.

Relying on more efficient irrigation techniques has yet to produce the expected water-saving results (Bouras et al., 2019). However, the more efficient use of this resource has allowed for expanding agricultural exploitation to regions with water scarcity.

As described in the following subsection, migration from rural areas into urban centres and abroad has been a consistent response in Morocco to the challenges of rural areas since the second half of the XX century (Berriane et al., 2021).

Climate Mobility

A common trend in Morocco's policies is the tendency to consider migration undesirable. For example, the National Strategy for Integrated Coastal Management states that rural areas should be provided with the means to resist the expansion of urbanised zones and choose to develop small and medium-sized centres equipped with the necessary socio-educational and logistical

facilities to retain part of the rural population inclined to migrate. While surveys in various countries indicate that environmental factors are not directly cited as the trigger for migration (Hoffmann & Zens, 2024), research in rural areas of Morocco led to more direct links between environmental degradation, namely increasing water scarcity, and out-migration from rural into urban areas (Ferreira Fernandes et al., 2023a; Ou-Salah, 2023).

However, it is essential to acknowledge that strategies that focus on reducing out-migration through supporting adaptation efforts and building resilience are not necessarily the best option. Instead, migration needs to be perceived in its complexity, neither as a solution for everything nor a problem to be solved, but as part of what can be classified as global change and development (de Haas, 2024). Therefore, it is more relevant to look at development holistically and understand the role of migration as a possible response that can produce better local outcomes (Lindegaard et al., 2024).

Water Management in Urban Areas

Various interventions are being implemented to manage water availability in Morocco, including investment in large engineering projects (Ministry of Youth, Culture and Communication, 2023). The National Water Plan has prioritised solutions such as diverting river water to dams and building a large desalination plant. Regarding distribution, in some regions, namely urban areas, different private companies have been awarded distribution management contracts, but there are concerns about various degrees of efficiency (Rezzouq, 2021).

However, if water demand continues to rise, these efforts may fall short (Figure 2). Therefore, more research is required to understand perceptions of water consumption in urban centres in Morocco, drawing from existing studies carried out in rural areas where water management is more studied, particularly in oases (Mahjoubi, 2022) and agricultural lands (Azemzi, 2021).

While large-scale investments in producing and distributing water are essential, they require substantial funds that could be directed toward the increasing energy needs of other sectors. With water (and electricity) utilities increasingly managed by decentralised, public-private partnerships across Morocco, aligning all stakeholders – including consumers – around responsible water usage is crucial. Communication and education are vital tools to encourage the rational use of resources, yet their full potential remains largely untapped.

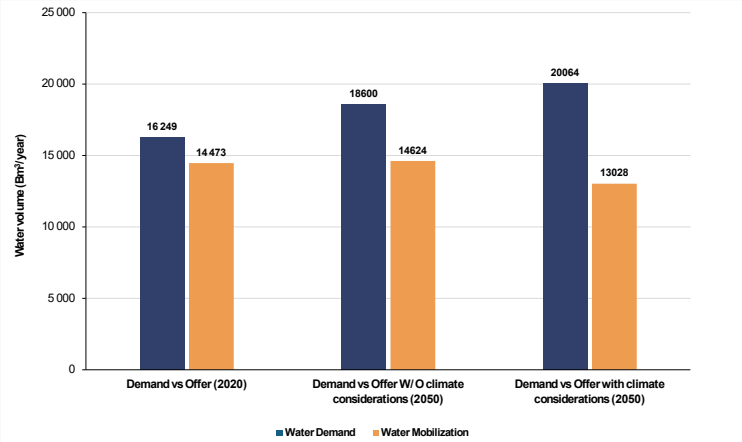

Figure 2. Projected water deficit over 2020-2050 (with and without climate change considerations) (World Bank, 2022).

Sustainability

The concept of sustainable development is defined in political circles and tries to reach uniform and universalist definitions. However, those definitions do not represent diversity (Telleria, 2022). Solutions that do not rely solely on technical fixes must be addressed, and communities must be involved in ontological

pluralism to imagine new solutions (Nightingale et al., 2020). By focusing on micro-level perceptions and experiences, researchers and policy-makers can gain insights into how individuals and communities perceive and navigate the impacts of climate change in personally significant ways (Burke, 2020). For example, in Morocco, religious beliefs are part of how people perceive and cope with environmental change (Ou-Salah et al., 2024). Having a more context-centred approach would allow for a better understanding of how these lived experiences inform local knowledge and, in turn, shape adaptive responses and resilience strategies. This process is particularly critical in countries like Morocco, where there is a lack of universal social protection that could support the populations in tackling the challenges of a deteriorating climate.

In its Ecological Threats report (2024), IEP highlights solutions related to micro-entrepreneurship and cooperatives to build resilience to climate shocks. For Morocco, Bouhazzama and Guenaoui (2020) provide more evidence of cooperatives' importance in improving social cohesion and ensuring development models based on democratic participation. Ferreira Fernandes et al. (2024b), when researching social perceptions regarding projections of future views of development, have also collected evidence that farmers' associations in Morocco are a necessary step in the development path. This study points out that local associations and cooperatives are perceived as important economic actors in rural areas since they increase the possibility of local employment.

Ferreira Fernandes et al. (2024b) also highlighted a common opinion among farmers to expand the exploitation of groundwater resources, to cope with the impact of climate change on surface water availability and increased demand for water. These resources, often used at rates that are faster than its replenishment, raise various concerns with the social perceptions of sustainability, namely, how farmers understand the concepts associated with intergenerational equity and the rights of future generations to resources.

Engaging in various sustainability models requires elaborating, implementing, and monitoring regulations to prevent private actors and local authorities from competing to attract investors, create jobs that could further degrade the environment, harm the public interest, and preserve natural resources.

Conclusion

Stepping away from dichotomous definitions of the negative and positive consequences of migration, community resilience, and sustainable development opens new possibilities for understanding the knowledge being constantly created by communities, which informs their actual responses and actions. Thus, engaging with communities to understand water consumption patterns and how to nudge behaviour could better support the institutional efforts being deployed regarding water production and distribution.

In this new era, the Anthropocene, locally-led responses aligned with the specificities of micro contexts need to be addressed to imagine new holistic solutions to development.

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A economia circular como inovação contra a poluição dos rios Tietê e Pinheiros

Circular economy as an innovation against pollution of the Tietê and Pinheiros rivers

André Buono Silveira

Resumo

Este estudo examina a poluição severa dos Rios Tietê e Pinheiros na Região Metropolitana de São Paulo (RMSP), resultante da urbanização desordenada e do despejo de esgoto não tratado. Apesar de décadas de investimento, os esforços tradicionais de despoluição apresentaram resultados modestos. Baseado em uma revisão de literatura, este trabalho propõe a economia circular como uma estratégia inovadora para combater essa poluição. A implementação de princípios circulares – como redução de resíduos, recuperação de recursos e manufatura sustentável – pode reduzir significativamente as cargas de poluentes e é apresentada como vital para a restauração dos rios.

Palavras-chave: Economia Circular, Água, Poluição, Rio Tietê, Rio Pinheiros.

Abstract

This study examines the severe pollution of the Tietê and Pinheiros Rivers in São Paulo's Metropolitan Region (MRSP), resulting from disorderly urbanization and the discharge of untreated sewage. Despite decades of investment, traditional depollution efforts have shown modest results. Based on a literature review, this work proposes the circular economy as an innovative strategy to combat this pollution. Implementing circular principles – such as waste reduction, resource recovery, and sustainable manufacturing – can significantly reduce pollutant loads and is presented as vital for restoring the rivers.

Keywords: Circular Economy, Water, Pollution, Tietê River, Pinheiros River.

André Buono Silveira
Universidade Aberta, Lisboa, Portugal
0000-0003-4360-8342

Introduction

This work aims to discuss the environmental impact of the pollution of the waters of the Tietê and Pinheiros Rivers in the Metropolitan Region of São Paulo, Brazil (MRSP), in addition to presenting the circular economy as an innovative proposal to combat this pollution.

Research Question: How can the principles of the circular economy be applied to reduce pollution and improve the environmental health of the Tietê and Pinheiros Rivers in São Paulo? Hypothesis: The implementation of circular economy principles can significantly reduce the discharge of pollutants into the Tietê and Pinheiros Rivers by promoting the reuse of materials, minimizing waste generation, and encouraging sustainable industrial and urban practices.

The research was carried out through a literature review and a case study on the environmental conditions of these rivers.

Circular Economy

The idea of circular economy first emerged in 1990, where the interconnection between the environment and economic activities was initially studied. The definition of circular economy is not static as it contains a broad spectrum of principles and proposals (Merli, Preziosi, & Acampora, 2018).

In the thought of Geissdoerfer (2017), the circular economy is defined as follows:

> A regenerative system in which resource input and energy waste, emission, and leakage are minimized by slowing down, closing, and narrowing material and energy cycles. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, reconditioning, and recycling. Second, we define sustainability as the balanced integration of economic performance, social inclusion, and environmental resilience. (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, p. 766).

The National Confederation of Industry (CNI) defines the circular economy as redesigning products and rethinking production, marketing, and consumption through reuse, remanufacturing, and recycling. It offers a sustainable alternative to the traditional linear model of production, consumption, and disposal (CNI, n.d.).

Great and increasing attention has been given to the topic of circular economy by academics and companies (Merli, Preziosi, & Acampora, 2018) and their approaches to "circular" business and the economic model, which assign slightly different emphases to the main components. Even so, they share several common principles, as indicated by (Weetman, 2019): a) Extend the life of materials and products, where possible, over several "use cycles"; b) Adopt the "waste = food" approach to help recover materials and ensure that biological materials returning to Earth are benign, not toxic; (c) retain the energy, water and other process inputs embedded in the product and material for as long as possible; d) Adopt systems thinking methods in the design of solutions; e) Regenerate or at least conserve nature and living systems and; f) Promote policies, taxes and market mechanisms that encourage product stewardship, for example, policies and norms of the "polluter pays" type.

Additionally, Klassen and Whybark (1999, as cited in (Erdiaw-Kwasie, Abunyewah, Yusif, & Erdiaw-Kwasie, 2023) discuss the concept of sustainable service, stating that "sustainable service involves the establishment of objectives, plans, and processes that determine the position of operations and the ability to respond to environmental issues and regulations". Authors now indicate the need to accelerate the process of promoting the circular economy, through the so-called circular disruption. A socio-technical system is needed that moves from the harmful "take-make-use-discard" model to more sustainable and socially desirable models that use circular strategies to reduce resource consumption and structural waste (Erdiaw-Kwasie, Abunyewah, Yusif, & Erdiaw-Kwasie, 2023).

The Environmental Problem in the Tietê and Pinheiros Rivers

São Paulo, Brazil, founded on January 25, 1554, remained a crossing point for drovers and pioneers until the end of the century. It was only from the mid-19th century that the city began to develop and grow in the wake of coffee cultivation and export. This growth is evidenced by the population evolution of the Metropolitan Region of São Paulo (MRSP) (Toledo, 2012; Waldvogel & Capassi, 1999), which grew from 28,500 inhabitants in 1881 to 15,198,900 in 1991 (Jorge & Salgado, 1996), reaching the current 22,048,504 inhabitants (BRASIL, 2022).

As the city grew, infrastructure challenges emerged. Trams, trains, public lighting, and utilities like water and gas were introduced. Avenues, bridges, and viaducts were built, and immigrants filled labor demands. To support expanding industries, electricity supply was prioritized. Additionally, flooded areas along the Tietê and Pinheiros Rivers were drained and urbanized to accommodate homes and businesses. Thus, it was decided, from 1937 onwards, to rectify the two, whose works took place from 1950 to 1960 (Pessoa, 2019).

The Metropolitan Region of São Paulo (MRSP), home to 22 million people across 39 municipalities, is one of the world's largest urban centers. Its rapid economic growth neglected environmental concerns, severely impacting the Tietê and Pinheiros Rivers.

For the analysis of the environmental condition of the mentioned rivers, the Water Quality Index (WQI), published by the Environmental Company of the State of São Paulo (CETESB), will be used. The WQI considers the following nine variables: fecal coliforms, pH, biochemical oxygen demand (BOD), total nitrogen, total phosphorus, temperature, turbidity, total residue, and dissolved oxygen. The WQI evaluation scale ranges from 0 to 100 points, classified according to Table 1, according to Appendix D (CETESB, 2020a):

Classification	Score
Excellent	79 < WQI <= 100
Very Good	51 < WQI <= 79
Regular	36 <WQI <=51
Bad	19 < WQI <= 36
Very Bad	WQI <= 19

Table 1. Classification ranges according to the WQI

The implementation of circular economy practices, such as waste reduction, resource recovery from waste, and reduction of pollutant discharges, could significantly improve the WQI of these rivers by reducing the BOD and nutrient loads.

The Tietê River

The Tietê River, the main river in São Paulo, stretches 1,100 km from Salesópolis to the Paraná River, flowing east to west. In 1937, local authorities rectified the river by filling floodplains and urbanizing its banks, enabling the construction of avenues and infrastructure.

After 45 km, the Tietê River reaches the city of Mogi das Cruzes, already in the RMSP where, from then on, for decades, it received the dumping of sewage and garbage without any treatment. It is estimated that the Tietê River received, by 2014, about 1,100 t/day of untreated sewage, of which 800 t/day came from residential and 300 t/day from industrial sources (Andrade & Melo, 2018). Currently, the estimate of the BOD/day load in the Tietê River basin, which indirectly represents the volume of sewage still discharged untreated, is in the order of 520 t BOD/day. According to the Environmental Company of the State of São Paulo (CETESB) which, among other attributions, monitors the quality of water in the State, the Tietê River has the following Water Quality Indexes (WQI) described in Table 2 according to Appendix M (CETESB, 2020b):

Station	2015	2016	2017	2018	2019	2020
02090	55	61	59	65	63	64
04200	15	17	16	17	20	23
02450	28	35	39	32	34	29
02600	72	84	81	82	75	82
02900	83	84	86	86	83	86

Table 2. WQI of the Tietê River – 2015/2020

It is noted that the river "dies" when it reaches the MRSP, whose measurement is indicated at stations 04200 and 02450, returning to present adequate WQI after 348km of passing through São Paulo, as measured at station 02600.

The Pinheiros River

The Pinheiros River, which extends for 25 km in the south of São Paulo, is a tributary of the Tietê River and was rectified in 1937 to urbanize its banks. During this process, a project was also created to reverse its course, allowing the formation of the Billings Dam, which supplies drinking water and generates electricity at the Henry Borden Plant, in Cubatão.

However, over the decades, the Pinheiros River has suffered from the dumping of sewage, garbage, and industrial waste, receiving little or no treatment. Currently, it is estimated that the BOD/day load in the Pinheiros River basin, which indirectly reflects the volume of sewage still discharged untreated, is approximately 95 tons per day. According to CETESB, the Pinheiros River has the following Water Quality Indexes (WQI) described in Table 3, according to Appendix M (CETESB, 2020b):

Station	2015	2016	2017	2018	2019	2020
04100	28	41	47	42	43	45
04250	17	17	21	20	27	28
04500	18	17	17	17	18	20
04900	16	17	15	15	15	18

Table 3. WQI of the Pinheiros River – 2015/2020

It is noted that throughout its length the Pinheiros River has contaminated waters and is unfit for consumption.

Aggressions to the Tietê and Pinheiros Rivers

From the researched bibliography it was possible to identify the following situations and relate them to the environmental problem of the Tietê and Pinheiros Rivers.

- Population increase (Crutzen & Stoermer, 2000) and (Gillings & Hagan-Lawson, 2014): The population increase in the Metropolitan Region of São Paulo (MRSP) occurred mainly at the end of the nineteenth century, driven by large migrations of European immigrants and people from other parts of Brazil in search of work. This resulted in higher water consumption and increased the need to use the Pinheiros River for energy generation.

- Intense urbanization (Crutzen & Stoermer, 2000), land-use change due to urbanization or traffic (Baede, Ahlonsou, Ding, & Schimel, 2001), land system change (Gillings & Hagan-Lawson, 2014): Urbanization and land-use changes in the São Paulo Metropolitan Region have driven rapid housing construction due to population growth. This expansion has had severe impacts on the Tietê and Pinheiros Rivers, primarily due to the discharge of untreated sewage.

- Physical modifications (Millennium Ecosystem Assessment, 2005; Bacelar-Nicolau & Azeiteiro, 2015): The river

rectification aimed to drain and urbanize banks for avenue construction. In the Pinheiros River, flow changes for power generation increased water speed, disrupted species reproduction, and removed natural flood-containment areas.

- Chemical pollution (Gillings & Hagan-Lawson, 2014): The release of chemicals and industrial waste into the Tietê and Pinheiros Rivers harms the ecosystem, worsened by São Paulo's industrialization. Poor agricultural waste disposal further degrades water quality and aquatic life.

- Emission of greenhouse gases into the atmosphere (Crutzen & Stoermer, 2000; Cavicchioli, et al., 2019): Polluted rivers like the Tietê and Pinheiros also emit greenhouse gases. Fertilizers and untreated sewage cause eutrophication, leading to fish deaths, foul odors, ecological imbalance, and methane and nitrous oxide emissions. Thus, the emission of these gases is a consequence of environmental pollution (Hao, et al., 2021; Schultz, 2021). It is important to mention that understanding the impacts on water, and the consequent interaction with the entire ecosystem, is challenging and significant (Sivapalan, 2011; Steffen, et al., 2004).

Impacts on Environment

Neglect of the Tietê River has led to lifeless stretches dominated by anaerobic bacteria. Industrial pollution and domestic sewage have degraded water quality, causing foul odors, flooding, and disease, prompting the population to demand action from authorities (Bueno & Henkes, 2016; Ribeiro, 2004).

Impact on water supply, irrigation, and fisheries

Urbanization and industrialization in São Paulo have deteriorated the quality of the waters of the Tietê and Pinheiros Rivers, due to the release of pollutants and untreated sewage. The failure in the collection and inspection system results in the death of fish and makes the waters unsuitable for supply, irrigation, and fishing. There is also a risk of contamination of groundwater near the Guarani aquifer. (Boehm, 2021; CETESB, 2020).

Impact on urban mobility in São Paulo

The irregular disposal of domestic waste in rivers causes serious environmental and social problems. The accumulation of waste in the riverbeds leads to siltation, intensifies floods and contaminates the water, harming aquatic fauna and flora. In addition, river pollution prevents the use of important waterways such as the Pinheiros and Tietê, aggravating urban congestion and generating excessive costs for society (Delijaicov, 2020).

Impact on people's health and the health system

River pollution, particularly heavy metals from untreated sewage, harms riverside communities by contaminating soil, water, and food, leading to illness in humans and animals. In the Tietê basin, toxic substances increase public health costs, damage the environment, and degrade biodiversity, negatively impacting the quality of life (Moraes, Mortatti, & Lopes, 2011; Ribeiro, 2004).

Impact on the social life of communities

Among the changes in lifestyle, the discontinuity of popular festivities, common on the waters of the Tietê, which on many occasions are no longer celebrated in view of the polluted waters and subject to causing diseases (Ribeiro, 2004).

Strategies for Minimizing Impacts

Efforts to decontaminate the Tietê and Pinheiros Rivers began in the late 1980s, with initial emphasis on the Tietê River. In 1992, the so-called Tietê Project effectively began, after strong social mobilization through a petition with

more than 1,200,000 signatures.

The first phase (1995-2000) involved US$1.6 billion to build 3,450 km of sewage network and install more than 1 million connections, benefiting 8.5 million people. The second phase (2000-2010) expanded the sewage treatment capacity and benefited 8.5 million people, with investments of US$2 billion. The third phase (2010) included the construction of another 1,350 km network and the installation of 718 thousand connections, increasing the treatment capacity by 42%, benefiting 5 million people. The fourth phase, which began in 2014, is underway and seeks to install 540 km of additional network and expand treatment capacity by 16%, benefiting 3.7 million people, at an estimated cost of US$900 million. In addition, integrated projects were launched, such as Tietê 2, Tietê 3 and Tietê 4, to connect the sanitation actions of the Tietê and the Pinheiros River (Ferreira, 2019; Camargo, 2018).

The Tietê Project showed positive results, with an increase in the sewage collection and treatment network in the MRSP. In 1992, 24% of the sewage of 15.4 million people was treated. In 2002, this percentage rose to 62% (17.9 million people), 70% in 2008 (19.2 million), 89% in 2019 and is expected to reach 92% in 2025, benefiting more than 22 million people.

The Novo Rio Pinheiros Project, started in 2019, aims to benefit 3.3 million people, connect 554 thousand properties to the sewage network and treat 4,600 L/s of sewage. It includes structuring works, interconnection networks, and improvements to existing facilities, like the Tietê Project, but focused on the Pinheiros River watershed (Ferreira, 2019; SÃO PAULO, n.d.).

Despite decades of investment, recent studies show that rivers remain polluted (Lavieri, 2021; Moraes N. G., 2022). The Tietê Project, aimed at improving water quality in the Tietê River and its tributaries, has yielded modest results considering the time and investment involved (Andrade & Melo, 2018). Therefore, it is proposed that combining the circular economy with traditional strategies could achieve the desired depollution outcomes for the Tietê and Pinheiros Rivers.

Circular economy can be integrated into the Tietê and Novo Rio Pinheiros Projects through techniques such as effluent treatment and reuse, recovery of nutrients (nitrogen and phosphorus) and heavy metals, and biogas production from organic waste. Reverse logistics and eco-design would reduce solid waste. These actions would decrease BOD, eutrophication, and contamination by toxic substances, improving water quality.

Possible Applications of the Circular Economy

The following aspects can be identified as benefits of the application of circular economy principles in the case of pollution of the Tietê and Pinheiros Rivers:

Reduction of solid/inorganic waste: The circular economy promotes sustainable production, leading to more durable products and reusable packaging, which reduces waste. However, improper waste disposal can still result in some waste entering rivers, carried by wind, rain, or inadequate sewage systems. Less waste overall reduces the likelihood of river contamination;

Reduction of chemical waste: sustainable production efforts also reduce the use, and consequently the disposal, of chemical components that often end up being discharged into the river without proper treatment;

Selective garbage collection: Selective garbage collection, a key feature of a sustainable city, helps reduce waste that could end up in rivers. The MRSP must make significant progress in this area as part of its efforts toward sustainability. While challenging, it is an achievable goal;

Innovation and New Technologies: The transition to a circular economy favors innovation by creating innovative solutions for the management of waste and pollutants, such as technologies that capture waste before it reaches waterways;

Education and Awareness: The implementation of the circular economy usually involves actions to educate and raise awareness among the population about the importance of correct waste disposal and environmental preservation, which can reduce pollution in rivers.

Industries and local businesses in São Paulo can adopt circular economy practices by incorporating recycled materials, improving resource efficiency, and minimizing waste through closed-loop systems. Incentives like tax reductions, subsidies, and green certifications can encourage businesses to switch to biodegradable or reusable packaging, directly reducing waste in rivers. Additionally, technology such as smart waste collection, real-time monitoring sensors, and advanced filtration can further prevent pollutants from reaching waterways. By combining sustainable manufact uring, policy incentives, and technological solutions, industries and businesses can play a crucial role in fostering a cleaner, more resilient urban water ecosystem.

Conclusion

The study addressed the pollution of the Tietê and Pinheiros Rivers, located in the Metropolitan Region of São Paulo (RMSP), and its environmental and social implications. The MRSP, one of the largest urban agglomerations in the world, faces serious problems related to population growth and disorderly urbanization, resulting in the uncontrollable dumping of sewage and garbage into the rivers. The Tietê River is the most compromised within the region, while the Pinheiros River has waters unfit for consumption along its entire length, reflecting a critical scenario of environmental degradation driven by years of neglect.

Pollution in urban areas is driven by growth, which seals soil and impairs rainwater runoff, causing flooding. River rectification and industrial waste disposal disrupt aquatic ecosystems and release greenhouse gases, worsening global warming. These issues negatively impact water quality, public health, urban mobility, and social life, limiting community events. To address pollution, strategies like waste removal and sanitation infrastructure have been introduced. Combining traditional methods with innovative approaches, such as the circular economy, is essential. This model minimizes waste and maximizes resource reuse through recycling, refurbishing, and redesigning products, creating a closed-loop system that reduces environmental impact and promotes sustainability.

Reducing waste and pollutants, improving selective garbage collection, and adopting innovative technologies can boost water recovery efforts. Raising public awareness and improving daily habits are crucial to ensuring environmental preservation is a shared responsibility, while promoting quality of life as a universal right.

In conclusion, circular economy strategies – such as waste valorization, resource recovery, and sustainable manufacturing – offer a transformative solution to combat pollution in the Tietê and Pinheiros Rivers. By integrating advanced technologies and fostering stakeholder collaboration, these practices can significantly reduce pollutant loads and improve water quality. However, challenges like policy gaps and funding limitations must be addressed. Future studies should explore scalability and long-term impacts, while immediate actions should focus on incentives, partnerships, and community engagement. Adopting circular economy principles is vital for restoring these rivers and building a sustainable urban future.

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Rega para agricultores familiares no contexto das alterações climáticas em Portugal: perceções, opções e necessidades

Irrigation for family farmers in the context of climate change in Portugal: perceptions, options and needs

Luís Moreno

Resumo

Ilustra-se o problema do uso da água na agricultura familiar em Portugal continental, com foco em: escolhas de irrigação feitas pelos agricultores; relação entre essas escolhas e as perceções da influência das alterações climáticas; condições e fatores que explicam maior ou menor propensão para manter práticas e para prever mudanças. Contando essencialmente com resultados do projeto AFAVEL (Agricultura Familiar e Valorização Territorial Sustentável, no contexto das Alterações Climáticas), mostra-se alguma incompatibilidade entre as perceções dos agricultores familiares sobre as alterações climáticas e o seu efetivo uso da água, bem como certas necessidades de soluções sociotécnicas e medidas de política pública.

Palavras-chave: Agricultura Familiar; Uso da Água; Alterações climáticas; Sustentabilidade.

Abstract

The problem of water use in family farming in mainland Portugal is outlined, focusing on: irrigation choices made by farmers; the relationship between these choices and perceptions of the influence of climate change; conditions and factors that explain greater or lesser propensity to maintain practices and to envisage changes. Based mainly on the results of the AFAVEL project (Family Farming and Sustainable Territorial Development in the context of Climate Change), some incompatibility is shown between family farmers' perceptions of climate change and their actual use of water, as well as certain needs for socio-technical solutions and public policy measures.

Keywords: Family Farming; Water Use; Climate Change; Sustainability.

Luís Moreno
Centro de Estudos Geográficos, Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Lisboa, Portugal
0000-0001-6507-1780

Introduction

Family Farming (FF) is a conceptual reality with multiple definitions, depending on the contexts and symbolic appropriations of individuals and groups, from academics to policymakers and civil society actors, depending on the interests involved and the objectives (Bosc et al., 2019). For our purposes, in Europe and Portugal, FF accounts for more than 90 per cent of the total (Eurostat, 2024a) and represents the highest water consumption, particularly in the southern European regions (Rossi, 2019; Eurostat, 2024b).

In this paper, we try to illustrate the problem of water use in FF in mainland Portugal by referring to the irrigation choices made by family farm managers and the relationship between these choices and perceptions of the influence of climate change. We also look at the conditions and factors that will explain a greater or lesser propensity to maintain practices and to foresee changes on farms, taking into consideration the challenges of FF addressed in numerous studies (we highlight Costa et al., 2018; Migliorini et al., 2018; Ebel, 2020; Wuepper, Wimmer & Sauer, 2020). The work essentially includes results of the research carried out as part of the AFAVEL project (Family Farming and Sustainable Territorial Enhancement, in the context of Climate Change; see ahead for details), involving the use of fieldwork in 2020 and 2021. However, the aim of this short paper is simply to illustrate a certain degree of mismatch between family farmers' perceptions (mental representations) of climate change and their agricultural water use practices, as well as the need for socio-technical solutions and public policy measures in the face of the water shortage challenges experienced.

Materials, methods, study scope and sources of family farmers' irrigation water

This work was mainly based on structured in-depth interviews with producers recognised as Family Farmers (FF), conducted by AFAVEL project partners, and involved visits to 130 farms in 15 municipalities in three Portuguese regions: Douro Litoral, Dão-Lafões and Alentejo. In the latter case, these are mainly municipalities in 'Alentejo Central', but also in 'Alto Alentejo' (Figure 1).

The results of the interviews were obtained from a 'convenience sample', which is not representative or even of the territories in which the sites observed are located, and which does not allow descriptive inferences to be made. In other words, the elements presented only have an illustrative value in terms of the expression of certain characterisation variables, and can only inspire relationship analyses. Thus, by showing illustrative elements of the situations studied (potentially indicative case studies), we were able above all to explore the relationships between certain attributes of the people interviewed and their opinions and behaviours, as well as to analyse the answers contextually.

In a basic characterisation, we found that all FF irrigated in some way. In the territories studied in the North and Centre, producers' use of water from groundwater wells and springs (or even watercourses) and combined sources dominates. In the part of the Alentejo that was analysed, the importance of wells and boreholes stands out, as well as dam irrigation perimeters and combinations of resources.

The combined forms / resources are, for example, on the same farm, borehole and well, or well and spring, and this diversity of origin of water resources was the main characteristic of the farms in Dão-Lafões (a region particularly favoured by natural conditions) that were the focus of attention.

These different sources of water for irrigation involve higher or lower access costs, with expenses that also vary depending on farm production (type and volume), the technical conditions for

the purpose, the type and origin of machinery and equipment (by purchase, inheritance, loan, hire, etc.) and other agricultural production factors. In the cases of the three study areas, the vast majority of these resources are entirely obtained by purchase, and are differentiating factors for the sustainability or prospects for continuity of the farms, despite considerable differences in each case.

Results and discussion: water uses and the perception of climate change

According to the study on which we rely, the vast majority of people interviewed recognised the existence of so-called 'climate change', with very similar weights among younger and older people (92% and 90% respectively), but it was slightly more significant among people with a higher level of education (94%, compared to 89% of those with no more than primary education). Other people, even though they've heard of it, say they haven't noticed any significant changes yet. The same goes for the feeling of consequences on their farm.

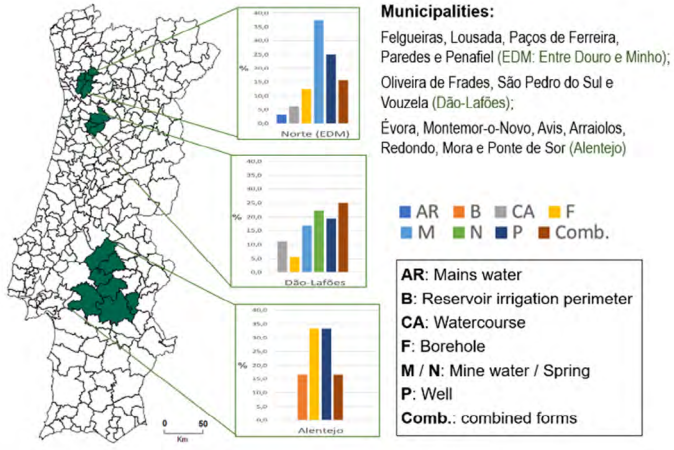
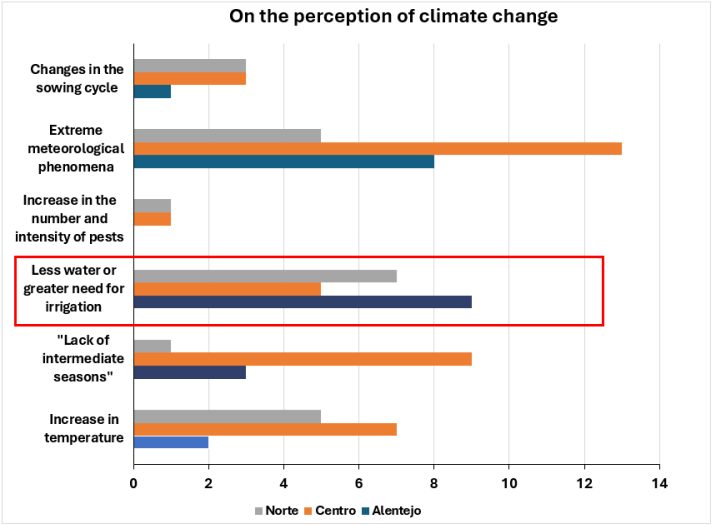


Figure 1. Municipalities where the interview surveys were carried out of the AFAVEL project and origins of the water used for irrigation (%)

Among the aspects that have been recognised as being associated with climate change (CC) extreme weather events and the absence of intermediate seasons were emphasised. Both show unequal representation, both in geographical terms (more in the Alentejo and the North) and in consequences throughout the year (especially less water available or greater need for irrigation), as well as being associated with other changes. The scarcity of water and the increased need for irrigation do indeed appear as consequences of the CC; only in the Centre / Dão-Lafões region the destruction and diminished quality of crops (due to fires and certain pests...) prevailed over the weight of adversities directly related to water shortage (Figure 2).



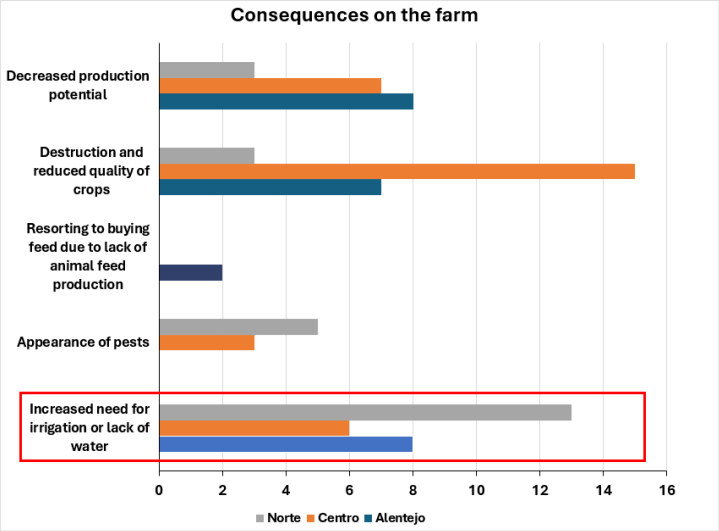


Figure 2. Perception among the producers interviewed of the existence of climate change and its influence on the farm

In any case, we can find in all the (considered) 'consequences of the CC' dimensions that we cannot easily dissociate from the availability of water, which translates into increases in the (complex, not just economic) costs involved for those who produce. A significant majority of the people interviewed considered that new needs and changes in cultivation techniques had arisen as a result of the CC above all greater / better regulation of irrigation or its increase, followed by changes in the calendar and type of crops – more so among those with more years on the farm and higher levels of education.

Most people also said they were concerned about preserving the properties of water and soil (with the exception of cases of very small farms, thus assuming limited impact, and more attention to quantity than quality), acting to control and manage water consumption in irrigation (with drip irrigation, filters, etc.), as well as controlling or reducing the use of phytopharmaceuticals and fertilisers and 'sustainability techniques' such as crop rotation, reusing organic matter, etc.

For these reasons - concerns about the quantity and quality of key resources - a majority of respondents (over 82%) said they feared significant implications of climate change in the more or less near future, with the main concern (over half of the cases) being water scarcity. As a result, there were declarations of intent to make changes in the coming years, mainly (more than half of the cases) investment in technical operating conditions, with the emphasis on reinforcing water supply or irrigation systems, greenhouses, agro-processing, etc.

Conclusion

According to the study, the issue of water use in Family Farming (FF) is largely a matter of concerns associated with perceptions or recognitions (mental representations) of climate change (CC) and its consequences for farms and territories. However, the relationship between mentions of a greater or lesser water shortage and climate change was not straightforward. On the one hand, a reduction in rainfall seems to have been less noticeable than an increase in its concentration, resulting in meteorological irregularity and extreme weather situations (temperature, rainfall and wind). On the other hand, the farmers who have focused most on intensification using conventional / traditional methods (sometimes drilling more boreholes) are the ones who have complained the most about water scarcity, adding their concerns to those of other people (farmers and actors relevant to FF) who have been more or less apprehensive about CC and its systemic consequences on farms and territories.

In the encounter between the recognised problems and the challenges to be faced, the study inherent to the AFAVEL project pointed to the need for investment in water retention structures and systems for their efficient use, thinking about solutions for individual and collective use which is associated with changes

in water use patterns, consistent with various studies but also in suitable cultivation options (more resistant to water shortages, such as traditional varieties and native species), as well as more diversified and better informed options in the relationship with markets and actors in the socio-territorial fabric. To this end, a whole dynamic of governance and innovation (technical, social, organisational...) will be important, in a logic of subsidiarity, around education, training, research, experimentation and extension.

Several of these aspects, diagnosed in 2020-21, are still valid, given the slow changes in the practices of a 'losing' FF (shrinking in Europe in general, and also in Portugal, in association with some rural depopulation) and insufficient support to ensure its resilience in the context of climate change. This support for the necessary investments would involve systemic improvements for the efficient use of water and would be part of the instruments for mitigating the effects of a system that has rewarded short-term technical and economic efficiency to the detriment of responding to the challenges of territorial sustainability. These challenges correspond to the need for cohesion, spatial planning and meaningful occupation, as well as diversification of options and opportunities for the most threatened areas of the territories, with an additional positive impact on urban areas.

Among the recipients of the results of the AFAVEL project, including those on the issue of irrigation and the resulting quality of farms and their territories, were various players in the agri-food system – some of them taking part in project activities – such as researchers, academics and others, but also political decision-makers and heads of farmers' and local development organisations concerned about qualified rural-urban links, as well as about sustainability in general and the role of water management in that process.

One of the instruments that emerged to boost the multiple innovation required was the policy measure embodied in the creation, at the end of 2021, of a protocol to set up the Centre of Competence for Family Farming and Agroecology (CeCAFA), "made up of farmers' organisations, local development organisations, entities from the national scientific system and public administration, and civil society organisations working in the area of Family Farming and Agroecology" (Moreno & Magalhães, 2021, p. 60). This initiative has given meaning to the work carried out and suggests that CeCAFA can favour a process of increasing efficiency in water management and irrigation, given the dimensions of the skills being mobilised.

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Cheias no rio Vez: uma análise social através da Pirâmide de Freytag

Floods in the Vez River: A Social Analysis through Freytag's Pyramid

Maria da Glória Salgado Gonçalves

Resumo

Este estudo analisa a gestão de cheias na bacia do rio Vez, Portugal, focando na integração entre dados técnicos e narrativas culturais. Através da aplicação da Pirâmide de Freytag e do método K-Means, classificam-se dados de caudal e precipitação, complementados pela análise de relatos jornalísticos e fontes históricas. Destacam-se duas abordagens complementares: a modelação hidrológica para a avaliação de riscos e a relevância dos registos digitais na formulação de políticas públicas sustentáveis. A conjugação de dados quantitativos com narrativas culturais proporciona uma base robusta para estratégias de gestão integrada. Estudos futuros devem aprofundar metodologias interdisciplinares.

Palavras-chave: Floods, Vez River, Freytag's Pyramid, Políticas Públicas.

Abstract

This study examines flood management in the Vez River basin, Portugal, focusing on the integration of technical data and cultural narratives. By applying Freytag's Pyramid and the K-Means method, flow and precipitation data are classified, complemented by an analysis of journalistic reports and historical sources. Two complementary approaches are highlighted: hydrological modelling for risk assessment and the relevance of digital records in the formulation of sustainable public policies. The combination of quantitative data and cultural narratives provides a robust foundation for integrated management strategies. Future research should delve deeper into interdisciplinary methodologies.

Keywords: Floods; Vez River; Freytag's Pyramid; Public Policies.

Maria da Glória Salgado Gonçalves
Centro de Estudos Globais, Universidade Aberta, Lisboa, Portugal
Department of Mathematics, Faculdade de Ciências, Universidade do Porto, Porto, Portugal

0000-0003-3627-5404

Introduction

Flood events, while primarily physical phenomena, carry significant narrative and cultural dimensions, particularly when analysed within social, historical, or environmental contexts. This dual nature of floods highlights their complexity and the need for interdisciplinary approaches to risk management and public engagement. In the Vez River basin, located in northern Portugal, riverine floods represent a growing concern, posing substantial risks to public safety, economic stability, and environmental integrity. These events disrupt daily life, damage critical infrastructure, and challenge local and national authorities' ability to respond effectively.

This study applies Freytag's Pyramid, a classical narrative framework, to the analysis of flood narratives in the Vez River basin. The model's five stages (exposition, rising action, climax, falling action, and resolution) are employed to structure and interpret flood events through historical data, hydrological modelling, and digital flood records. This approach aims to bridge the gap between technical assessments of flood risk and the public's cultural and emotional engagement with these events. By aligning narrative stages with hydrological and meteorological data, such as river discharge and precipitation, the study provides a multidimensional understanding of floods, contextualising both their physical impacts and social ramifications.

The motivation for this research stems from the need to develop innovative communication strategies that resonate with stakeholders, enhancing both public awareness and policy-making. In regions like the Vez River basin, where over 979 flood incidents (between 1900 and 2015) have been recorded alongside significant socio-economic consequences, there is an urgent need for strategies that integrate technical insights with culturally significant narratives. Such an approach not only enriches the academic discourse on flood management but also delivers practical tools for decision-makers, urban planners, and local communities.

By combining quantitative data clustering (using the KMeans algorithm) with Freytag's narrative structure, this paper aims to reveal how flood narratives evolve and influence public perception, preparedness, and response. This interdisciplinary perspective underscores the potential of integrating hydrological modelling with cultural storytelling to create more effective, inclusive, and sustainable flood management strategies. Ultimately, the study seeks to contribute to a deeper understanding of how technical and cultural dimensions of flood events interact, driving better practices for risk communication and disaster resilience.

Literature Review: Freytag's Pyramid

The work of Gustav Freytag (1816–1895), a German playwright and theorist, has had a significant influence on contemporary literature, particularly through his contribution to the synthesis and analysis of narrative structures (Kelly-Quattrocchi et al., 2024). He is especially recognized for his conception of the "Freytag Pyramid", a model that organizes the narrative into distinct phases (Figure 1), aiding in the analysis of dramatic construction. Furthermore, his work explores the concept of catastrophes within narrative structures, emphasizing how these events can be used to generate tension and development within the plot. "It is the supposition of actualism, the belief that past events are the outcome of processes seen in operation today" (Charlton, 2007, p. 27).

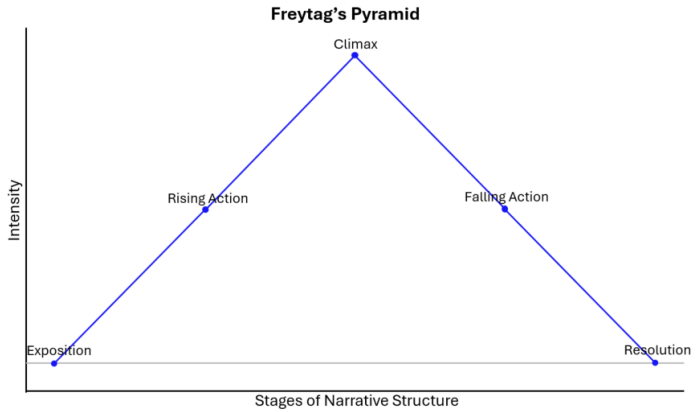

Figure 1. Freytag's Pyramid.
Source: Created by the author in Jupyter Notebook, 2025.

This theoretical framework underscores the dynamic interplay between emotional and social dimensions, offering valuable insights into how floods shape individual and collective experiences, perceptions, and memories. Such an understanding is essential for interpreting immediate responses to these events and for devising long-term resilience strategies.

Climatic and meteorological data, along with their modelling, enable the prediction of in situ tensions (Cortés et al., 2024). Of particular interest is understanding the adaptive variation of biodiversity in response to the impacts of climate change. Climate alterations significantly affect the ecology of mountain pastures at various levels, including shifts in the growing season's dynamics (John et al., 2024). In light of research findings on climate change (Borowiec, 2023; Cortés et al., 2024; Mayer et al., 2023), biodiversity adaptation (De Ron et al., 2022), and humanity's capacity to adapt to increasingly catastrophic floods, it becomes imperative to rethink strategies for ensuring overall safety and survival.

Effective communication of the climate crisis is vital for social acceptance (Borowiec, 2023). Freytag's framework provides a structured approach to analysing the emotional and social impact (Ciğerci & Yıldırım, 2023) of floods, supporting adaptive strategies and resilience to climate challenges.

Materials and Methods

Study area

The Vez River Basin is in the northwest of mainland Portugal (Figure 2). This figure, which illustrates the study area, was constructed using data from OpenStreetMap (https://www.openstreetmap.org). Geographically, the basin is situated approximately between 41.80° and 41.95° latitude north and 8.30° and 8.12° longitude west. The basin is almost entirely contained within the municipality of Arcos de Valdevez, which gives the river its name. The Vez river discharges into the Lima River, an international basin named after the town of Ponte de Lima.

This is a small basin on a local scale, covering 263 km², with the river stretching 36 km in length (Bellu et al., 2016; Carvalho-Santos, Nunes, et al., 2016; Fonseca et al., 2018). Its geometry is not elongated but rather close to an oval shape. The basin is characterised by a mountainous fluvial geomorphology, reaching an altitude of 1,410 metres, with its highest points situated towards Melgaço.

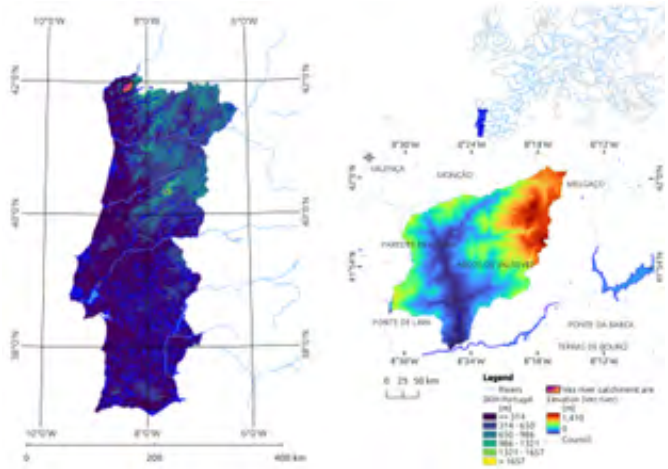

Figure 2. Geographical location and the drainage basin of the Vez River basin.

Geologically, the Vez River Basin is predominantly composed of granite, a substrate characterised by low infiltration capacity (Bellu et al., 2016). The native forest, primarily consisting of oak (*Quercus robur*) and cork oak (*Quercus suber*) trees (Carvalho-Santos, Sousa-Silva, et al., 2016), is largely concentrated in the northwestern part of the basin. Meanwhile, the terraced fields of Sistelo, a distinctive feature of mountain pastures, dominate the north-central region. These ecosystems play a crucial role in sustaining local biodiversity (Carvalho-Santos, Nunes, et al., 2016) while also mitigating seasonal flooding by enhancing water infiltration and reducing surface runoff. As natural buffers, they help regulate hydrological dynamics, contributing to overall watershed stability. By mitigating peak flows, they act as natural buffers against seasonal flooding, contributing to greater hydrological stability. The vegetation cover, combined with biodiversity, provides key advantages for adaptive responses to climate change (Cortés et al., 2024).

Data

The study utilised data from the *Sistema Nacional de Informação de Recursos Hídricos* (SNIRH: https://snirh.apambiente.pt/) spanning three decades, from 1 October 1960 to 30 September 1990. The selected variables for analysis included the discharge rate from the Pontilhão de Celeiros (Discharge) station, as well as precipitation data from the Casal Soeiro (raincs) and Cabreiro (rainc) stations. It is worth noting that the discharge variable contains 1951 missing data points, while precipitation has none. The discharge data exhibit gaps throughout the analysed period, with significant missing records in the years 1974, 1975, 1976, and 1977, accounting for 365, 365, 366, and 365 days, respectively. Other years show smaller counts of missing data, such as 1960 (12 days), 1967 (31 days), and 1978 (273 days), highlighting notable inconsistencies in the time series. No treatment was applied to the missing data, as it was determined that the missing values had no significant impact on the adopted model, as described in the Methods section. Additionally, the dataset available on Mendeley (https://doi.org/10.17632/z5fnkgngdg.2), covering the period from 1900 to 2015, was used. It includes news articles related to floods in the Vez River basin area.

Methods

For the development of this document, particularly the literature review, a search was conducted using the Dimensions database, and relevant articles were selected and cited throughout the text. Additionally, articles from previous research, stored in Zotero, were considered. These include studies conducted by various researchers focusing on the case of the Vez River Basin.

The KMeans clustering algorithm, implemented in Jupyter Notebook using the Scikit-learn package, was applied with 5 clusters, corresponding to the five stages of Freytag's Pyramid,

to analyse flood narratives. Data from the National Water Resources Information System (SNIRH) were utilised to provide a comprehensive overview of flood-related variables. For days with missing discharge data, precipitation data were also excluded, as it corresponded to the same day. The choice of K=5 clusters reflects the complexity of hydrological events in the Vez River basin. Although the elbow method initially suggested K=2, the model was trained for K=5, allowing for a clearer distinction between critical events (Clusters 2 and 3), transitional states (Clusters 1 and 4), and stable periods (Cluster 0). According to the Silhouette Score criterion, for k=5, values of 0.69, close to 1, indicate good separation between clusters (Figure 3). This ensures a comprehensive representation of the data, capturing natural variability and extreme events essential for understanding flood risks and watershed dynamics.

Although the silhouette score for $K = 6$ is slightly higher than for $K = 5$, the choice of $K = 5$ was guided by both methodological and conceptual considerations. The clustering approach was aligned with the five stages of Freytag's Pyramid, ensuring consistency in the narrative analysis of flood events. Furthermore, increasing K beyond 5 did not yield substantially improved interpretability, as the focus remained on distinguishing flood events. A higher silhouette score alone does not necessarily indicate a superior clustering solution, as excessive subdivision may yield statistically well-defined clusters that are less hydrologically meaningful. Thus, the choice of $K = 5$ provides a balanced trade-off between data structure, domain relevance, and interpretability, allowing for a clear distinction between critical flood phases while maintaining coherence with the event classification framework. The selection of the optimal number of clusters was not solely based on the highest Silhouette Score but also on hydrological interpretation and the relevance of the clusters to the study.

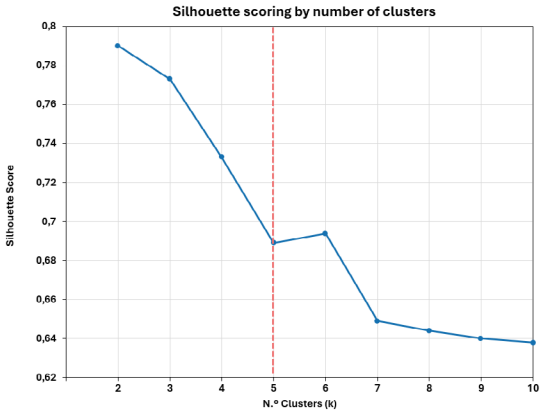

Figure 3. Silhouette score.
Source: Created by the author in Jupyter, based on kmeans with SNIRH data (1960/1990), 2025.

Subsequently, a pyramid was created based on data from the digital flood registry available at https://doi.org/10.17632/z5fnkgngdg.2, which includes news reports about floods. This pyramid follows the structure of Freytag's model and has been applied to flood narratives in the context of risk communication and awareness. In point 3, Historical and Cultural Narratives, we recount personal stories from the past shared by residents, specifically focusing on "Lininha da Valeta," a prominent figure in Arcos de Valdevez, immortalized in a painting on her house's door, and featured in the 'MurArcos' Festival.

Results

The data analysis was conducted using Freytag's model to structure flood narratives within the Vez River basin. Through the five stages of the model, data from the SNIRH and the digital flood record were examined, focusing on identifying vulnerabilities, understanding the dynamics of action, and assessing the resolution of flood impacts.

Local Impact Narratives

This section applies Freytag's model to analyse the flood narrative within the Vez River basin, focusing on key phases of the event and the associated hydrological data (Figure 4 and Table 1).

The flood cluster analysis (Figure 4) identifies instances where high discharge occurs despite low precipitation, and vice versa. These discrepancies can be attributed to various hydrological factors, particularly the lag effect.

In cases of low precipitation but high discharge, river discharge may be influenced by prior upstream rainfall in mountainous regions, as well as delayed runoff contributions. Additionally, groundwater discharge can sustain river discharge even when surface precipitation is minimal.

Conversely, high precipitation but low discharge can result from soil infiltration and temporary water storage in floodplains and saturated areas. The lag effect in surface runoff also plays a significant role, as rainwater may take time to reach the river. Furthermore, although to a lesser extent, evapotranspiration losses can substantially reduce the immediate contribution of precipitation to river discharge. It is also important to note that K-Means clustering does not consider only discharge but incorporates multiple hydrological variables and identifies outliers, which influence the clustering outcomes (Table 1).

Rising Action Exposition

Introduction to the context of the riverside community, the river's state prior to the event, and the initial conditions. For the variables under study with daily data, the following values were obtained: discharge 4.88 m^3/s; raincs 0.65 mm; rainc 0.80 mm.

The moment when the river level begins to rise due to heavy rainfall, melting, or other natural factors. Data values obtained were: discharge 19.50 m^3/s; raincs 13.38 mm; rainc 14.08 mm.

Climax

Tension escalates as the river overflows, causing panic, evacuations, and material and emotional losses. Data values obtained were: discharge 77.92 m^3/s; raincs 65.08 mm; rainc 66.96 mm.

Falling Action

The most critical point of the event, as the flood peaks, leading to the collapse of barriers or the isolation of populations. Data values obtained were: discharge 370.12 m^3/s; raincs 41.12 mm; rainc 41.63 mm.

Resolution

The recession of the waters, the response from authorities, recovery efforts, and reflections on the impact and lessons learned. Data values obtained were: discharge 44.84 m^3/s; raincs 34.16 mm; rainc 31.47 mm.

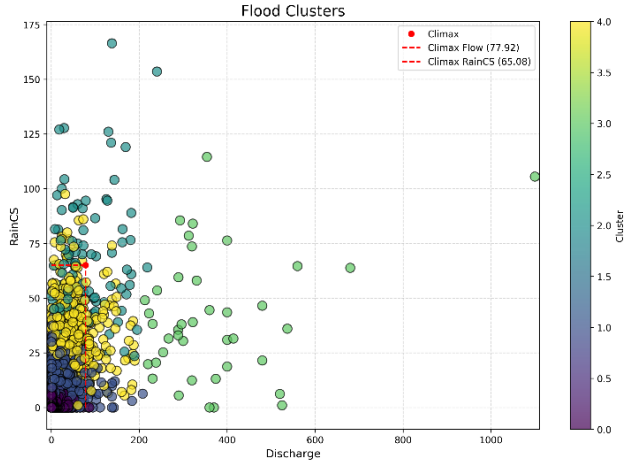

Figure 4. Flood Cluster Analysis: Discharge and Precipitation in the Context of the Flood Climax.
Source: Created by the author in Jupyter, based on kmeans = KMeans(n_ clusters=5) with SNIRH data (1960/1990), 2025.

STAGE	CLUSTER AND N. °	DISCHARGE (M^3/S)	RAINCS (MM)	RAINC (MM)
Exposition	0; 7150	4.88	0.65	0.80
Rasin action	1; 1189	19.50	13.38	14.08
Climax	2; 101	77.92	65.08	66.96
Falling action	3; 40	370.12	41.12	41.63
Resolution	4; 525	44.84	34.16	31.47

Table 1. Hydrological Data and Clustering Stages for the Vez River Flood Event (including average values with outliers).
Source: Created by the author in Jupyter,based on kmeans = KMeans(n_ clusters=5) with SNIRH data (1960/1990), 2025.

As illustrated in Figure 4 and further supported by Table 1, the model identifies that when discharge and precipitation values reach or exceed the climax, the resulting floods are significantly more catastrophic in terms of their impact. These impacts are detailed in the subsequent two models.

Narratives in Risk Communication and Awareness

Communication campaigns through news articles to prevent or mitigate the impacts of riverine flooding were structured according to Freytag's model to maximise emotional impact and public engagement. The exposure to flood risk in the Vez River basin focuses on critical infrastructure and vulnerable residential areas. Issues related to sewage systems and the Valetas area are highlighted, with impacts recorded in locations such as S. Cosme to Vilela Road, Rio de Moinhos, Trasladário, Prozelo (Ponte Velha), and Rua Nunes de Azevedo. Bridges and footbridges, such as the Ázere Medieval Bridge and Vilela Bridge, experience substantial pressures, exacerbated by inadequate urban drainage, particularly in municipal buildings where drainage systems redirect water into the streets. In total, 79 critical vulnerable locations, 979 recorded incidents, 1449 intervention actions, and 215 consequences were documented.

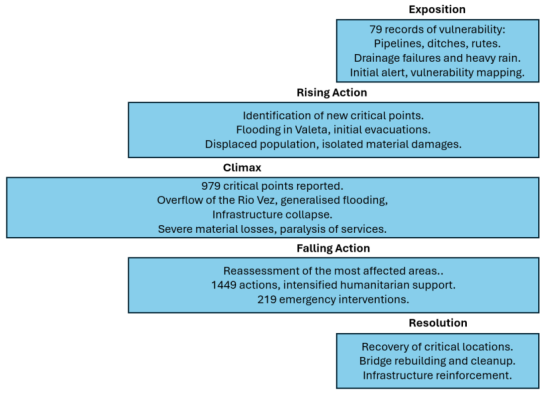

Figure 5. Freytag's Pyramid for the Vez River Basin.
Source: Created by the author in Jupyter Notebook, based on the news (1900/2015), 2025.

In economic terms, losses were recorded in crop fields, uprooted trees, and damage to both public and private infrastructure, with total losses exceeding 1 million escudos (in 1999 and 2000 alone). Substantial expenditures were required for repairs, reconstructions, and clean-ups, including housing, bridges, and drainage systems. Furthermore, economic losses stemmed from the disruption of agricultural and commercial activities, as well as providing support to affected populations. In terms of transportation, road closures, construction delays, and mobility difficulties were reported due to power outages and road blockages. These consequences reflect the scale of material, social, and environmental damage caused by the floods.

Historical and Cultural Narratives

Exposition

The Valeta neighbourhood, celebrated for its historical and cultural significance, has frequently been the focus of media coverage related to flooding from the Vez River and the Vila Fonche stream. An analysis of news articles revealed 69 references to the term Valeta, underscoring its prominence in discussions about flood-related challenges. The terms Consequences, Actions, and Vulnerability were identified 60, 169, and 26 times, respectively, reflecting the persistent social, economic, and environmental challenges affecting the area.

Rising Action

Over the decades, recurring floods have profoundly impacted the identity and daily life of Valeta's inhabitants. A notable example is the long-term resident of house no. 53, a two-storey property repeatedly inundated by floodwaters. This individual, who resided in the neighbourhood for over a century and passed away at the age of 101, exemplifies the enduring struggles faced by the community. Structural interventions, such as the construction of a retaining wall along the riverside avenue by the former Roads Authority, have often been criticized for exacerbating flood risks rather than mitigating them.

Climax

Flood events in Valeta are cause of severe disruptions and significant hardship. Rising waters impede traffic and parking, while debris accumulation and sewage overflow further deteriorate living conditions. Residents frequently report unpleasant odours and sanitation issues, with floodwaters breaching homes. Although a newly installed sewage pumping station has been promoted as a solution, its proximity to residential areas has raised concerns about potential structural failures and environmental contamination. These apprehensions are further aggravated by delays in implementing comprehensive flood mitigation strategies, leaving many sceptical about the adequacy of existing measures.

Falling Action

The consequences of recurrent flooding impacts of recurrent flooding extend beyond immediate physical damage, with long-term socio-economic implications. Local businesses have experienced declining activity, prompting some proprietors to consider relocating. Efforts to stabilise the area, such as replacing sand with gravel and revitalising the riverbanks, have been implemented, but these initiatives have yet to fully address residents' concerns or restore confidence in the area's resilience.

Resolution

Valeta remains a cultural and historical landmark near sites like Pontilhão da Valeta. Its recovery relies on sustainable, community-focused strategies to protect residents and revitalize the local economy, highlighting the need for integrated urban planning to reduce flood risks and improve quality of life in vulnerable areas.

Figure 6. The face of the floods in Valeta.
Source: Photo by JF S. Salvador, Vila Fonche e Parada, depicting a painting by Daniela Guerreiro, featured in O Minho, 2024.

The local narratives of the Valeta neighbourhood paint a compelling picture of resilience intertwined with vulnerability, underscoring the urgent need for sustainable measures that not only reduce flood risks but also safeguard the area's rich historical and cultural heritage for generations to come.

Discussion and Conclusions

Discussion

A simplified model of the Vez River's fluvial landscape was employed to analyse flood events, confirming their recurring nature and partially supporting the principle of actualism (Charlton, 2007). However, this principle is challenged by the differences between past and present fluvial and climatic processes, largely attributed to climate change (Cortés et al., 2024). The long-term evolution of ecosystems, as highlighted in recent studies (Borowiec, 2023; Cortés et al., 2024), reflects the impact of these changes, including human adaptation to extreme events like the recurrent floods in the Vez River basin.

Technical Analysis

Modelling of discharge and precipitation data reveals a consistent pattern of catastrophic flood events, indicating that, on average, one severe event occurs annually. These findings underline the ongoing hydrological risks and provide insights into flood management strategies in the region.

Social and Cultural Reflection

The social response to flooding is also crucial, with human resilience demonstrated through adaptive strategies, such as structural reinforcements in areas like Valeta, often impacted by catastrophic events (Bellu et al., 2016; Fonseca et al., 2018; Gonçalves, 2024). An example of individual resilience is the case of House 53, which illustrates how local communities cope

with these threats. Such adaptations combine both practical and social elements, shaping disaster risk reduction strategies.

Concluding Remarks

The evidence of climate change's localised impacts necessitates a reconsideration of assumptions about Earth's surface processes. Climate change is permanently altering ecosystem dynamics, requiring continuous adaptation from both human and natural systems to manage evolving risks, such as flooding.

Conclusions

The study demonstrated how the application of Freytag's Pyramid can integrate distinct approaches, such as using the KMeans method to classify discharge and precipitation data into five clusters, analysing press narratives, and reviewing historical accounts. This combination provides risk managers with a more comprehensive perspective. We identified 40 catastrophic floods in the Vez River Basin, based on discharge and precipitation data, suggesting that the frequency of severe events may exceed one per year on average.

However, the study has some limitations, including incomplete data and the constraints of the narrative approach, which may not capture all the nuances of historical and social events. Given these limitations, future research should explore the integration of more complete datasets, including meteorological, social, and cultural data, to provide a more holistic and accurate understanding of flood risks. Furthermore, it is crucial to promote public policies that consider both scientific and cultural perspectives, to develop a more adaptive, inclusive, and resilient flood management strategy in the face of climate change.

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Erosão fluvial e mutações morfométricas do Oued Bouregreg no setor de Maaziz (Planalto Central, Marrocos)

Erosion fluviatile et mutations morphométriques de l'Oued Bouregreg dans le secteur de Maaziz (Plateau central, Maroc)

Idriss Sammaa
Ali Taous
Mohammed Yazami Ztait
Imad El-Ghalmi

Resumo

Este estudo centra-se na análise do processo de erosão fluvial e das consequentes alterações morfométricas no leito do rio Bouregreg, em Maaziz. Os resultados indicam uma erosão intensa, particularmente durante cheias de grande caudal, manifestando-se como erosão na base do leito, deslizamentos e colapsos das margens. Para além desta atividade erosiva, os afluentes laterais e os leques aluviais também contribuem para a metamorfose fluvial. Entre 1970 e 2020, o leito do rio sofreu ligeiras modificações morfométricas, caracterizadas pela preservação do mesmo estilo fluvial, apesar de alterações locais como o estreitamento do canal e a formação de bancos de cascalho.

Palavras-chave: Oued Bouregreg, Maaziz, erosão fluvial, alterações morfométricas.

Idriss Sammaa
sammaaidriss@gmail.com
Ali Taous
ali.taous@usmba.ac.ma
Mohammed Yazami Ztait
mohammed.yazamiztait@usmba.ac.ma
Imad El-Ghalmi
Département de Géographie, Faculté des Lettres et des Sciences Humaines Sais-Fès, Université Sidi Mohamed Ben Abdellah, Fès, Maroc
elghalmi2014imad@gmail.com

Abstract

This study focuses on analyzing the fluvial erosion process and the resulting morphometric changes in the Bouregreg Riverbed at Maaziz. The results indicate intense erosion, particularly during high-flow floods, manifesting as undercutting, sliding, and bank collapse. In addition to this erosive activity, lateral tributaries and alluvial fans also contribute to fluvial metamorphosis. Between 1970 and 2020, the riverbed underwent slight morphometric modifications, characterized by the preservation of the same fluvial style, despite local changes such as channel narrowing and the development of gravel bars.

Keywords: Oued Bouregreg, Maaziz, fluvial erosion, morphometric changes.

Introduction

A côté du transport de matériaux, le processus d'érosion et de sédimentation jouent un rôle fondamental dans la détermination de la morphologie fluviale (A. Taous, 2005). A l'échelle du lit fluvial, l'intensité des processus d'érosion est variable dans le temps et dans l'espace. Elle dépend de plusieurs facteurs physiques (hydrodynamisme des cours d'eau, leurs profils longitudinaux, leurs styles morphologiques…).

Dans la vallée du Moyen Bouregreg, secteur de Maaziz, le lit fluvial de l'oued est soumis à des processus érosifs qui peuvent s'exercer aussi bien verticalement en profondeur du chenal que latéralement. Ces processus d'érosion s'accélèrent manifestement lors des crues torrentielles occasionnées par les averses intenses. Ils sont très variés (modalités et intensités), et ils différent selon les conditions bioclimatiques et les contextes géomorphologiques (A. Taous, 2005). En fait, l'érosion fluviatile le long de l'Oued Bouregreg constitue un risque hydro-géomorphologique majeur et délicat du fait de l'ampleur de ses conséquences environnementales et socio-économiques. A l'échelle de la plaine alluviale de Maaziz, l'érosion des berges occasionnent des pertes en sol estimées à environ 78 hectares durant 50 ans (période 1970-2020), soit une dégradation annuelle moyenne de 1,56 hectares.

Sur le plan morphodynamique, l'action de l'érosion par sapement des berges aux moments des crues de forte énergie hydrodynamique, accompagnée d'une forte activité latérale des cônes de déjection, engendre une modification assez profonde des morphologies fluviales. Durant la période 1970-2020, le lit a enregistré un amenuisement de sa largeur d'environ 19% et une augmentation de sa longueur de 6%, ce qui signifie un changement des caractéristiques morphométriques des méandres. L'objectif de cet article est de mettre en évidence l'impact du processus d'érosion fluviatile sur la morphométrie du lit fluvial du Moyen Bouregreg dans le secteur de Maaziz, durant la période 1970-2020, tout en analysant les formes d'érosion observées et les changements morphométriques détectés à l'échelle des méandres durant la période étudiée.

Methodologie et Outils du Travail

La méthodologie adoptée dans cet article s'est basée essentiellement sur :

Travail du terrain : il vise à identifier et caractériser le risque d'érosion des berges et son extension spatiale le long du tronçon, à travers l'observation, les mesures morphométriques et la prise des photos.

Exploitation des fonds cartographiques couvrant la zone d'étude : elle a pour objectif de déterminer les caractéristiques physiques de la zone d'étude, étude diachronique du chenal actif et les incidences liées au risque d'érosion des berges (cartes topographiques, 1/25000 et 1/100000, feuilles de Maaziz et Khemissèt, et carte géologique, 1/10000, feuille de Khemissèt), des photos-aériennes (échelle 1/25000, 1970) et images satellitaires (Google Earth : missions 2003 et 2020). Le traitement de ces documents a été effectué à l'aide du logiciel ArcGis 10.4.

Etude de la morphométrie des méandres : elle consiste à caractériser quantitativement et analyser la géométrie de la sinuosité du lit fluvial, en déterminant les principaux paramètres morphométriques (M. J. Selby, 1985) (fig. 1).

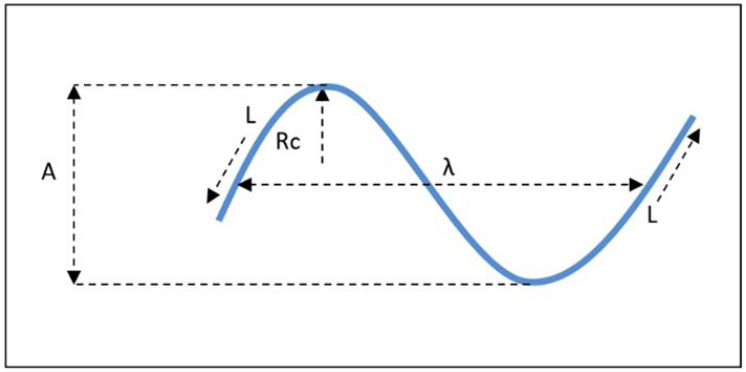

Figure 1 . Principaux paramètres morphométriques des méandres d'un cours d'eau (selon M. J. Selby, 1985)

λ : longueur d'onde, A : amplitude des méandres, L : longueur du talweg entre deux inflexions de même sens, Rc : rayon de courbure, Is : indice de sinuosité (L/λ)

L'amplitude des méandres est mesurée entre deux sommets de sinuosités de phases opposées (M. J. Selby, 1985). Sa valeur est calculée en traçant l'enveloppe externe de méandrage et une perpendiculaire pour obtenir une valeur moyenne correcte (J. R. Malavoi et J. P. Bravard, 2010) ; tandis que le rayon de courbure se mesure en faisant passer un cercle par les deux points d'inflexion d'une sinuosité complète, ou en ajustant l'arc du cercle à la forme la plus proche de la sinuosité si le méandre est tortueux. Les deux paramètres se calculent de préférence dans un méandre homogène.

Presentation de la Zone d'Etude

Le tronçon de cours d'eau étudié se situe dans la moyenne vallée du Bouregreg dans le secteur de Maaziz, où il est développé au sein d'une cuvette à fond large, creusée dans les terrains du plateau inférieur du plateau central marocain (G. Beaudet, 1969). Il s'étend du Sud au Nord sur un linéaire de 12,8km, depuis la zone d'Ait Brahim jusqu'aux environs du douar d'Ait Azzouz (fig. 2). Le cours de l'Oued Bouregreg dans ce tronçon constitue une limite naturelle séparant le territoire de deux communes territoriales qui appartiennent à la province de Khemissèt. A l'échelle de sa confluence avec l'Oued Tanoubart se termine le territoire de Tiddas (rive gauche) et débute le territoire de Maaziz (rive droite). Ici, l'Oued Bouregreg développe une plaine alluviale large et draine de l'amont vers l'aval les douars de deux communes de Tiddas et Maaziz (Ait Ali Ou Amer, Ait Brahim, Ait Driss Raja…), connues par leurs activités agricoles aussi bien pluviale qu'irriguée, et le pâturage.

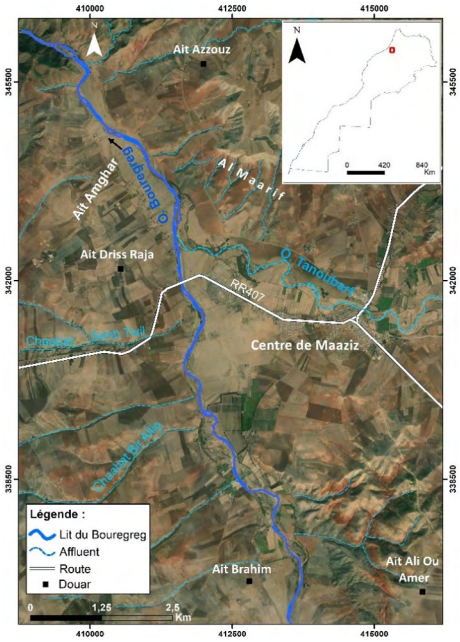

Figure 2 . Localisation géographique du secteur de Maaziz (extrait de l'Images de Google Earth,1/25000, 07/11/2021)

Dans le secteur de Maaziz, la vallée de Bouregreg est développée principalement dans des terrains secondaires formés d'argiles et basaltes altérés du Trias, surmontées par les marnes, grès et calcarénites du Miocène (fig. 3). La nature tendre des terrains traversés par l'oued permet le développement d'une vallée large caractéristique, dissymétrique de part et d'autre du cours d'eau. L'évasement de la vallée a permis la conservation de véritables héritages quaternaires sous formes des terrasses alluviales, cônes de déjection, glacis et nappes colluviales plus

ou moins épaisses. Dans ce contexte, le cours d'eau présente une pente longitudinale faible (2‰), et reçoit l'affluent nommé Oued Tanoubart sur la rive droite, en aval du centre Maaziz. Son tracé est orienté SE-NW, et montre un chenal unique sinueux et divagant dans un fond de vallée à soubassement argilo-basaltique triasique.

Les versants triasiques sont très sensibles aux processus d'érosion et d'altération. Les basaltes interstratifiés n'offrent pas de résistance aux processus érosifs et les terrains montrent par ailleurs de nombreuses formes de ravinement et de solifluxion (A. Benmohammadi, 1991). Des paysages de badlands sont observés de part et d'autre du cours d'eau sur les versants.

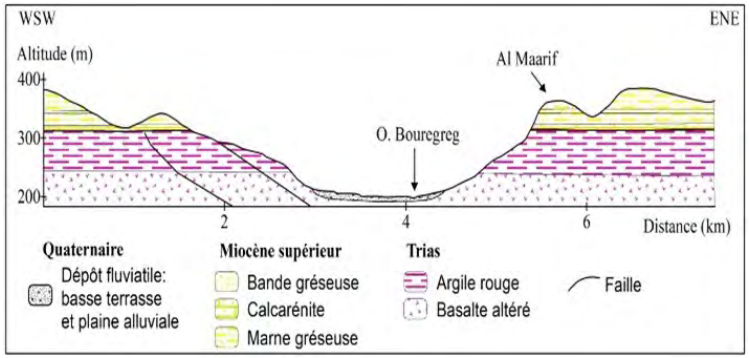

Figure 3 . Coupe géologique de la vallée de Bouregreg à Maaziz (d'après la carte géologique de Khemissèt, 1/100000, 2002 ; et observation du terrain)

Sur le plan hydroclimatique, le secteur d'étude est doté d'un climat méditerranéen semi-aride caractérisé par des fluctuations saisonnières assez importantes (A. Marghich, 2004). La chronique 1980-2016 montre qu'il s'agit d'un régime pluviométrique méditerranéen irrégulier, caractérisé par de fortes variations interannuelles et saisonnières ; les précipitations maximales atteignent 689,8mm à Maaziz (station Lalla Chafia). Les températures mensuelles moyennes oscillent entre 8°C et 27°C (fig. 4). Ces conditions climatiques contrôlent les écoulements irréguliers de l'Oued Bouregreg, caractérisés par des crues de fort hydrodynamisme et des étiages d'été plus ou moins sévères. Les crues automnales, hivernales et printanières sont souvent violentes et leurs débits de pointe peuvent dépasser 1200 m3/s (exemple : 1296 m3/s le 30 Novembre 2010 à la station Lalla Chafia).

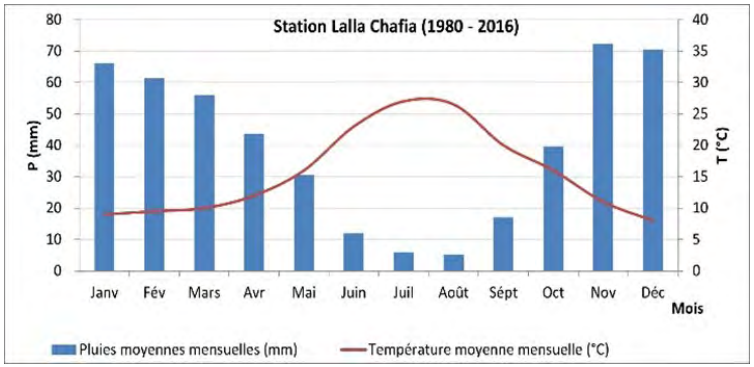

Figure 4 . Diagramme ombrothermique montrant les caractéristiques des précipitations et de température de Maaziz (station Lalla Chafia, 1980-2016)

Resultats et Discussions

Le long du secteur d'étude, le processus d'érosion est fréquent et présente des formes multiples. Il varie selon la nature lithologique des terrains encaissants, l'intensité du courant hydrique et la situation des berges par rapport aux cônes de déjection et affluents latéraux, leur hauteur, leur composition granulométrique, la morphologie du chenal, présence ou absence de la ripisylve… l'étude de terrain a permis d'identifier trois principaux types de processus, à savoir :

Sapement de berges

Il s'agit d'un processus mécanique qui conduit à l'enlèvement de matériaux constitutives des berges et à la modification de leur morphologie, notamment celles situées dans les concavités des méandres. Il s'agit de sapements de berges qui s'activent lors des forts écoulements de l'oued ; par leur menace, ces sapements préoccupent depuis longtemps la population locale et les paysans de la vallée de Bouregreg, vu les pertes en sols et cultures développées sur la plaine alluviale, et leur incidence socio-économique.

Lorsque la morphologie du fond est très large, le sapement associé à la migration des méandres, est généralement très actif. Dans la partie amont de la vallée, à proximité d'Ait Brahim, l'étroitesse de la vallée concentre et accélère la vitesse d'écoulement et le sapement des berges est très actif latéralement. Lors des décrues, l'écoulement affecte le pied des berges, ce qui contribue à l'effondrement de ses unités supérieures. Par exemple, à Ait Amghar (Ph. 1), le recul de la berge entaillée dans la basse terrasse est quantifié d'environ 90m durant 50ans (1970-2020). Elle est strictement influencée par les apports transportés par l'Oued Bouregreg, en plus de son affluent Oued Tanoubart.

Photo 1 . Berge fortement sapée en rive gauche du Bouregreg à proximité de douar d'Ait Amghar à Maaziz (26/08/2017).

Glissement de berges

Le glissement de masse des berges est un processus mécanique qui affecte les berges moins stables et relativement cohérentes. Il correspond au déplacement d'une partie de la berge le long d'une surface de cisaillement (Ph. 2). Il se déclenche le plus souvent dans les moments des basses eaux et les décrues, lorsque l'écoulement affecte le pied des talus séparant le lit de l'oued et sa plaine alluviale. Les plus exposées à ce type de dynamique sont les berges situées dans les concavités des méandres et relativement riches en limons et argiles.

La saturation en eau du sol développé au sommet de la berge ou la surcharge de celle-ci par des activités anthropiques (agricultures, constructions…) exercent un poids supplémentaire et influencent son équilibre dynamique. Lors des décrues, l'affouillement des bas de berges implique leur déséquilibre et le déclenchement de glissement, plus particulièrement lorsque les matériaux sont peu drainants puisque riches en argiles et limons. Ce type est observé dans les larges tronçons du Bouregreg, où les berges sont bien développées et façonnées par des méandres de forte sinuosité.

Photo 2 . Berge glissée en rive droite du Bouregreg dans le secteur d'Ait Brahim (26-05-2021)

Effondrement de berges

L'effondrement de la berge correspond au déplacement brutal d'une partie des sédiments des horizons supérieurs de la berge vers son pied. Dans le cas où les berges sont très cohérentes, l'érosion par le courant au pied de la berge peut conduire à la création des zones de surplomb (G. Degoutte, 2002), et favoriser l'effondrement brutal de ses unités supérieures, qui peut alimenter un éboulement. Ces phénomènes se produisent souvent pendant les moments des hautes eaux. Les interventions anthropiques peuvent favoriser l'accélération de ce processus. L'agriculture exercée sur la plaine alluviale et le défrichement de la ripisylve perturbent parfois l'équilibre et la stabilité de la berge et favorise l'effondrement de son horizon supérieur. Aussi, la mise en place des seuils de déviation de l'eau perturbe l'écoulement et favorise la genèse de l'érosion latérale dans le pied de la berge et permet l'effondrement et l'éboulement de ses unités supérieures. Ce type est observé au niveau du tronçon aval de Chaabat Bir Alig en rive droite de Bouregreg, et principalement dans le cas des berges cohérentes, moyennement hautes et à granulométrie limono-sableuse (Ph. 3).

Photo 3 . Effondrement d'une berge en rive droite du Bouregreg en amont du pont de RR 407 (26/05/2021)

En définitif, il ressort de cette analyse que l'évolution des berges reste globalement faible et leur dégradation périodique traduit la réponse du Bouregreg au régime hydrologique. La dynamique des berges dépend aussi des interventions anthropiques multiples à l'échelle de la plaine alluviale et le lit fluvial. Les observations du terrain et l'étude diachronique de la situation des berges, en comparant les années 1970 et 2020, montrent que le recul des berges est relativement lent. Les pertes en sols de terres agricoles durant les cinq dernières décennies sont évaluées de 78 hectares (23 ha sur la rive gauche et 55 ha sur la rive droite). Ainsi, d'après ces résultats, les pertes annuelles moyennes en surfaces des terres agricoles seraient d'environ 1,56 hectares à Maaziz (tab. 1).

Potentiel actuel en terres agricoles (ha)	Pertes rive gauche en 50 ans (ha)	Pertes rive droite en 50 ans (ha)	Pertes totales en 50 ans (ha)	Pertes annuelles moyennes (ha)
675	23	55	78	1,56

Tableau 1 . résultats de l'essai de quantification des superficies des pertes en terres agricoles par sapement des berges dans le secteur de Maaziz entre 1970 et 2020

Impact de l'érosion fluviatile sur la morphométrie de l'Oued Bouregreg

Les résultats de l'étude diachronique du lit moyen de l'Oued Bouregreg à Maaziz, et l'essai de quantification des mobilités morphologiques du chenal de l'oued, montrent que ce dernier a subi des changements plus ou moins profonds. Il tend globalement vers le rétrécissement de sa largeur. Durant les années 1970, les valeurs de largeur obtenues sont majoritairement importantes, puisque la valeur maximale enregistrée était 69 m, à proximité de douar Ait Brahim. Cette situation indique sur le plan hydro-géomorphologique, l'importance de l'écoulement fluvial

(succession des crues) d'une part, et l'action érosive latérale d'autre part.

L'évolution durant la période 1970 et 2020, indique en gros une diminution de la largeur puisque les moyennes enregistrées sont respectivement de 44m en 1970 et 36m en 2020, même si certains secteurs ont connu des changements inverses, avec augmentation de la largeur. C'est le cas par exemple des secteurs d'Ait Aissa, ainsi qu'au niveau du pont de la route régionale RR407 et à l'aval du tronçon à proximité du douar Ait Azzouz (fig. 5). L'étude des indices morphométriques des méandres et leur évolution temporelle nous a permis de constater de légères variations dans l'ensemble du tronçon (tab. 2). En effet, la valeur de la longueur d'onde est caractérisée par une régression assez importante, notamment durant la période 1970-2020 (diminution de 21%) ; puisque sa valeur moyenne a passé de 947m à 750m. Quant à l'amplitude des méandres, les moyennes enregistrées durant les trois périodes sont respectivement 230m, 378m et 323m ; c'est-à-dire une augmentation de 64% entre 1970 et 2003, et une diminution de 14% entre 2003 et 2020, et un accroissement de 40% lorsqu'on considère toute la période entre 1970 et 2020.

En ce qui concerne la longueur du talweg entre deux inflexions successives (longueur d'onde), elle a subi en moyenne une augmentation de 16% durant la période 1970-2003 et une régression de 29% dans la période 2003-2020 et 17% entre 1970 et 2020 (tab. 2). Le rayon de courbure présente des valeurs d'évolution négatives ; les moyennes enregistrées sont respectivement 207m, 195m et 142m durant les trois périodes, avec un taux de régression de 6% entre 1970 et 2003, 27% entre 2003 et 2020 et 31% entre 1970 et 2020. L'indice de sinuosité sur l'ensemble du tracé a subi de légères modifications, puisque le taux de variation est de 9,5% entre 1970 et 2003, -3,2% entre 2003 et 2020 et environ 6,1% durant l'ensemble de la période 1970-2020. On a constaté aussi qu'il y a plus de méandres abandonnés dans le cas de 2020 qu'auparavant, ce qui traduit que le tracé a subi durant les dernières décennies une dynamique latérale relativement importante.

	1970	2003	2020	Taux d'évolution (%) 1970-2020
Longueur réelle (km)	12,1	13,2	12,8	+6
Largeur moyenne (m)	44	32	36	-19
Longueur d'onde (m)	947	940	750	-21
Longueur du talweg (m)	1103	1280	909	-17
Amplitude (m)	230	378	323	+40
Rayon de courbure (m)	207	195	142	-31
Indice de sinuosité	1,15	1,26	1,22	+6

Tableau 2 . Taux d'évolution des indices géométriques et morphométriques des méandres de Bouregreg à Maaziz Durant la période 1970-2020

D'après l'étude diachronique du lit de Bouregreg (fig.5) basée sur la superposition des trois tracés fluviaux durant les trois années 1970, 2003 et 2020, nous pouvons ressortir les remarques suivantes :

— En 1970 : Le lit de Bouregreg correspondait à un chenal unique sinueux, avec un indice de sinuosité qui avoisine 1,15. Sa longueur était de l'ordre de 12,1km et sa largeur oscillait entre 10 à 69m. Nous pouvons également mettre en évidence d'après la photo-interprétation l'existence des portions plus larges à ramification de chenaux secondaires caractérisées par des bancs alluviaux longitudinaux peu végétalisés.

— En 2003 : on constate une migration latérale du lit de Bouregreg. La longueur réelle du lit avoisinait 13,2km et sa largeur variait de 12 à 66m. L'indice de sinuosité est égal à 1,26, ce qui indique un style fluvial plus sinueux et divagant. Durant cette période, le tracé de l'oued est caractérisé par l'apparition des boucles de méandres dans trois sites différents (Ait Aissa, Ait Brahim et l'aval de la confluence avec l'Oued Tanoubart).

— En 2020 : Le rétrécissement du lit de Bouregreg et sa migration latérale ont permis l'apparition de nombreuses barres caillouteuses, généralement longitudinales, riches en galets et parfois en blocs gréseux et basaltiques (observation de terrain). Ces barres fluviatiles se développent principalement dans des zones à pentes assez fortes. La migration latérale et l'érosion par sapement permettent le développement des méandres, avec parfois l'apparition des chenaux secondaires séparés par des bancs alluviaux. La longueur du lit a atteint 12,8km, et sa largeur moyenne est de l'ordre de 36m. Les taux d'évolution des indices morphométriques des méandres durant la chronique 1970-2020 sont majoritairement négatifs (tab. 2). Notons que la migration du lit peut être expliquée dans certains lieux par l'action des cônes de déjection, qui poussent le chenal de l'oued vers la rive opposée, tel que le cas du sous tronçon situé directement en amont du pont de RR407 (fig. 5). Ici le courant des ravins (chaabats) a engendré l'accumulation des dépôts sur la rive gauche du lit, ce qui a favorisé le rétrécissement de ce dernier et sa migration vers la rive droite. Cette migration est quantifiée d'environ 38m entre 1970 et 2003, 41m entre 2003 et 2020 et environ 103m entre 1970 et 2020 (fig. 5).

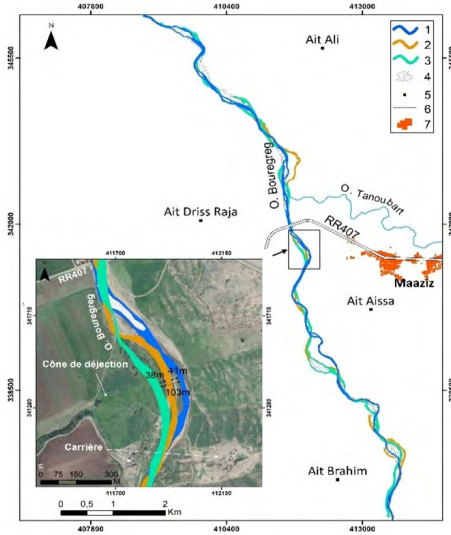

Figure 5 . Evolution spatio-temporelle du tracé du lit de l'Oued Bouregreg à Maaziz durant les années 1970, 2003 et 2020 :

1. Tracé du lit en 2020 ;
2. Tracé du lit en 2003 ;
3. Tracé du lit en 1970 ; 4. Barre alluviale ; 5. Douar ; 6. Route ; 7. Agglomération. Sur l'image on observe le détail dans le cas de l'influence du cône latéral en amont du pont de la route RR407.

La comparaison de cette tendance morphométrique avec le cas du tronçon de Larbaa Sehoul dans le Bas Bouregreg montre en gros, la même évolution. Le chenal actif a conservé le même style fluvial, puisque l'indice de sinuosité n'a pas connu un grand changement (de 1,53 en 1970 à 1,49 en 2020). En définitif, malgré de légères modifications, le lit du Bouregreg dans le tronçon de Maaziz n'a pas subi de véritables changements du tracé depuis le début des années 70 jusqu'au 2020, à l'exception de quelques sous tronçons situés essentiellement dans des sites de cônes de déjection et en amont du pont de Maaziz. Les traces des interventions anthropiques ont été observées durant cette période, des constructions et des carrières ont été installées sur les deux rives du Bouregreg, ainsi que le changement du paysage agricole, matérialisé par l'augmentation de la superficie agraire. En gros, ces interventions humaines ont eu de faibles influences localisées sur la morphologie du chenal. Les légers changements du lit observés et quantifiés à l'échelle du tronçon de Maaziz sont généralement liés à l'activité des processus érosifs aux moments des crues torrentielles et à la dynamique latérale des cônes de déjection. Le type de substrat friable et l'absence du couvert végétal jouent un rôle déterminant dans l'accélération de ravinement à l'échelle des versants et contribue à l'évacuation d'importantes quantités de matériaux qui sont déplacés vers le lit fluvial. Cet apport latéral, ajouté à l'apport longitudinal issu de l'amont, implique la perturbation de l'équilibre dynamique et favorise l'évolution du tracé. En revanche, la stabilité relative de certains transects étroits est due à l'influence du substrat géologique et le contexte géomorphologique.

Conclusion

Il apparait donc, que le processus d'érosion fluviatile engendré par la dynamique de Bouregreg dans le secteur de Maaziz est très actif, notamment aux moments des crues de fort hydrodynamisme. Il se manifeste essentiellement par le sapement, le glissement et l'effondrement des berges non cohérentes. Les

processus d'érosion sont influencés également par l'activité des cônes de déjection et affluents latéraux. L'étude diachronique du tracé du Bouregreg depuis 1970 jusqu'à 2020 a permis de retracer l'évolution spatio-temporelle récente du chenal actif. En effet, dans un contexte de sapement de berge et de divagation des méandres, malgré de légères modifications de détail observées localement, le tracé de l'Oued Bouregreg a conservé globalement le même style fluvial, avec un indice de sinuosité proche de 1,2. Ce qui caractérise ce type de cours d'eau évoluant en contexte géomorphologique de plateau. La mise en place des travaux d'aménagement transversaux et longitudinaux le long du cours d'eau (murs de protection, barrages, radiers…) est une priorité pour atténuer le risque lié à l'érosion et conserver les biens de la population locale.

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Impactos hidro-morfo-sedimentares da barragem de Sidi Chahed e mutações da paisagem fluvial do baixo vale do Mikkès (bacia do Sebou, Marrocos)

Impacts hydro-morphosédimentaires du barrage Sidi Chahed et mutation du paysage fluvial de la basse vallée du Mikkès (bassin du Sebou, Maroc)

Imad El-Ghalmi
Ali Taous
Idriss Sammaa
Lahcen Ouiaboub

Resumo

Este estudo examina os impactos hidromorfossedimentares da barragem de Sidi Chahed no rio Mikkès, situado na bacia do Saïs (bacia do Sebou, Marrocos). Foram utilizados levantamentos de campo, amostragem de sedimentos e análises longitudinais e transversais para avaliar as variações no regime de fluxo, na deposição de sedimentos e na morfologia do canal. Os resultados indicam que a retenção pela barragem reduziu significativamente o transporte de sedimentos a jusante, modificou a geometria dos meandros e alterou a dinâmica fluvial natural. Essas mudanças provocaram incisão do canal e triagem dos sedimentos, evidenciando a influência das infraestruturas hidráulicas nos rios.

Palavras-chave: Barragem de Sidi Chahed, Rio Mikkès, Morfologia Fluvial, Dinâmica de Sedimentos, Impacto Fluvial.

Imad El-Ghalmi
elghalmi2014imad@gmail.com/
Idriss Sammaa
sammaaidriss@gmai.com
Docteur en Géographie, FLSH – Saïs Fès, USMBA-Fès, Maroc
Ali Taous
ali.taous@usmba.ac.ma
Département de Géographie, EqR. MNADSS, FLSH – Saïs Fès, USMBA-Fès, Maroc
Lahcen Ouiaboub
Département de Géographie, Laboratoire. TED, FSHS, UIT-Kenitra, Maroc
lahcen.ouiaboub@uit.ac.ma

Abstract

This study examines the hydromorphosedimentary impacts of the Sidi Chahed Dam on the Mikkès River within the Saïs Basin (Sebou Basin, Morocco). Field surveys, sediment sampling, and longitudinal and cross-sectional analyses were used to evaluate variations in flow regime, sediment deposition, and channel morphology. The results indicate that dam retention significantly reduced downstream sediment transport, modified meander geometry, and disrupted natural fluvial dynamics. These changes have led to channel incision and sediment sorting. The findings highlight the effects of hydraulic infrastructure on river systems and provide useful insights for integrated river management in semi-arid environments.

Keywords: Sidi Chahed Dam, Mikkès River, River Morphology, Sediment Dynamics, Fluvial Impact.

Introduction

Les barrages, en tant qu'infrastructures hydrauliques, exercent une influence majeure sur les paysages fluviaux des vallées situées en aval. Ils modifient profondément le fonctionnement des cours d'eau, en altérant à la fois leur régime hydrologique naturel et leur morphologie fluviale. Le barrage de Sidi Chahed, édifié en 1997 sur l'Oued Mikkès (affluent du Sebou) dans le Prérif, illustre bien ces transformations. Conçu pour réguler les débits et répondre aux besoins en eau destinés à l'irrigation et à l'approvisionnement domestique, ce barrage retient une part importante des eaux et des sédiments transportés depuis le Moyen Atlas et le plateau du Saïs. Cette interception perturbe les dynamiques naturelles du cours d'eau en aval, entraînant des modifications morphologiques et hydrologiques notables. Ces changements ne sont pas sans conséquence sur l'environnement et les activités humaines. La réduction de l'apport sédimentaire et la modification du régime hydraulique impactent la biodiversité aquatique, l'érosion des berges et la qualité des sols agricoles. Par ailleurs, les populations riveraines, dont l'économie repose en grande partie sur l'agriculture et l'élevage, doivent s'adapter à ces nouvelles conditions hydriques, ce qui soulève des défis en matière de gestion des ressources en eau et de résilience des écosystèmes locaux. En se basant sur les documents cartographiques, photos-aériennes, images satellitaires et observation de terrain, nous présentons dans cette étude les principaux résultats préliminaires sur les phénomènes évoqués ci-dessus.

1. Presentation de la Zone d'Etude

Le tronçon de vallée étudié s'inscrit dans la partie septentrionale du bassin versant d'Oued Mikkès dans le domaine des collines prérifaines. Il s'étend sur environ 55 km, depuis la sortie de l'oued du Saïs jusqu'à sa confluence avec Oued Sebou, au niveau du douar Oulad Jrar. Le barrage sidi Chahed se trouve à l'entrée du domaine prérifain, juste à l'amont du centre rural de Mikkès (ph. 1). Il a une capacité de retenue de 170Mm3 et une hauteur de 60 m au-dessus des fondations. Sa retenue s'allonge sur plus de 7km de long et s'étale sur plus de 1000 hectares de superficie. Ce barrage régularise en moyenne annuellement des volumes d'eau d'environ 40Millions de m3. Il avait pour but le renforcement à moyen et à long terme de l'approvisionnement en eau potable de la ville de Meknès et l'irrigation de1200 ha, notamment les terres situées en aval, le long de la vallée.

Photo 1 . Le barrage Sidi Chahed

1.1. Contexte Physique

Sur le plan géologique, le bas Mikkès façonne sa vallée dans un domaine caractérisé par une complexité structurale et une grande variété lithologique donnant un paysage de colline marneuses et argileuses très ravinées. Il s'agit du domaine des nappes prérifaines, qui correspond au décollement d'une partie du matériel tertiaire des zones externes venant charrier un important olistostrome prérifain (F. Amraoui, 2005). En outre, des plissements tardifs ont provoqué la surrection d'anticlinaux

à cœur jurassico-crétacé des rides prérifaines qui apparaissent en bordure sud du Prérif (A. Brahim, 1983). Ces rides présentent une superposition des calcaires liasiques reposant directement sur le substratum triasique argileux (B. Cherai, 2009). Elles sont accidentées et affectées de plissements récents, plio-quaternaires (A. Michard et al. 2008). Elles sont traversées profondément par la vallée du Mikkès.

Sur le plan climatique, la zone d'étude se caractérise par un climat méditerranéen marqué par des variations saisonnières importantes. Ce climat, allant du semi-aride au subhumide selon les zones, joue un rôle clé dans la dynamique hydrologique et écologique de la zone d'étude. Les précipitations, principalement concentrées durant la saison hivernale, sont irrégulières et oscillent entre 400 et 600 mm par an, tandis que la période estivale est dominée par une sécheresse prolongée et des températures élevées pouvant atteindre 35°C.

1.2. Contexte Humain

Administrativement, le bassin versant de la basse vallée de l'Oued Mikkès relève de la région de Fès Meknès. Il draine les territoires de deux provinces : Province de Meknès et province de Moulay Yacoub. La population est très dispersée en douars éparses ou regroupée en agglomérations d'importance variable. Selon les recensements des dernières décennies, la population des deux provinces était de 106775 habitants en 1994 ; 118607 habitants en 2004 ; 141613 habitants en 2014 et 210410 habitants en 2024.

2. Methodologie

L'évaluation des impacts du barrage Sidi Chahed sur la morphologie fluviale et le paysage de la basse vallée du Mikkès s'est basée sur :

— l'analyse diachronique comparée des cartes topographiques (feuille Béni Ammar 1/50 000, 1942), des photos aériennes (1/25000, mission 1962) et des images satellitaires (Google Earth 2001 et 2021) ;

— les observations de terrain (effectuées en 2022) ont permis de compléter les analyses diachroniques et de faire les prélèvements des échantillons pour analyse granulométrique. Les analyses granulométriques du matériel alluvial grossier du lit de l'oued, sont effectuées in situ en utilisant le protocole de M.G.Wolman, (1954).

— les analyses de laboratoire ont concerné la granulométrie des sédiments fins par tamisage usuel normalisé Afnor.

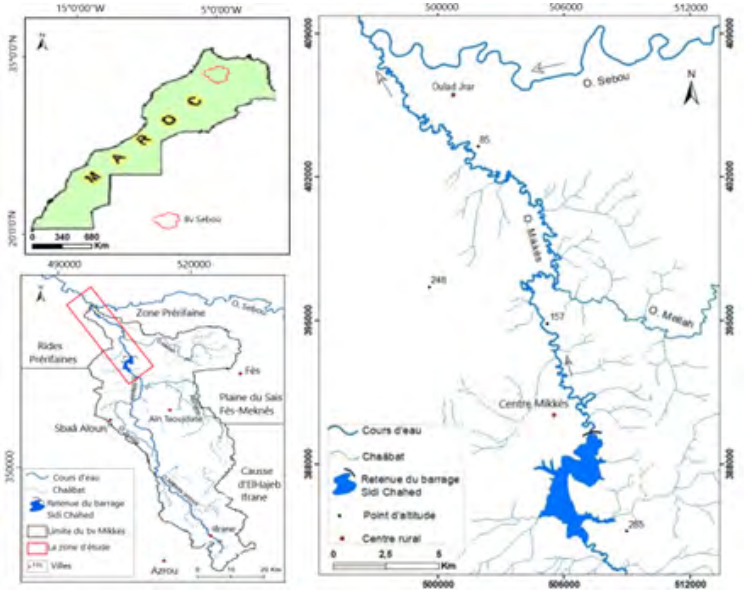


Figure 1 . Situation géographique de la vallée du Bas Mikkès et du barrage Sidi Chahed

3. Resultats et Discussions

3.1. L'impact du Barrage sur la Morphologie et la Mobilite de l'Oued

Comme dans d'autres barrages du Maroc, le barrage de Sidi Chahed a des impacts immédiats et durables sur le paysage hydro-morphologique de la vallée, tant en amont qu'en aval de la digue. L'un des effets les plus évidents réside dans la modification du régime hydrologique du cours d'eau en aval et la formation d'un lac de retenue en amont. Depuis sa mise en service, le barrage a supprimé le rôle morphogénique des crues en aval, réduisant significativement le transport des matériaux sédimentaires et provoquant des changements notables dans la dynamique du lit de l'oued (G.P.Williams et al., 1984 ; G.M.Kondolf., 1997). L'impact des barrages sur la morphologie des oueds marocains est bien documenté. Par exemple, les travaux menés sur l'Oued Bouregreg en aval du barrage Sidi Mohamed Ben Abdellah ont montré que les fluctuations du niveau de la retenue influencent fortement le fonctionnement hydro-sédimentaire du cours d'eau, modifiant ainsi la structure du lit fluvial et des berges (A. El Gharbaoui, 1981 ; Ait Brahim et al., 2020). De même, dans le bassin de l'Oued Sebou, la réduction du transport solide due aux barrages a entraîné une incision du lit et une diminution de la mobilité latérale du cours d'eau (M. Snoussi et al., 2002). Ces transformations ont été mises en évidence dans le cas de l'Oued Mikkès grâce à l'analyse de documents cartographiques, de photos aériennes et d'images satellitaires sur plusieurs décennies. Les résultats des mesures morphométriques effectuées sur le tronçon en aval du barrage, dans le secteur du Centre de Mikkès, montrent une évolution significative du tracé du Bas Mikkès après la construction du barrage Sidi Chahed. En réduisant la variabilité naturelle des débits et en retenant une grande partie des sédiments, le barrage a favorisé l'encaissement du lit, diminuant ainsi la dynamique latérale et les processus de recharge sédimentaire (Z. Qadem., 2020).

Années	1945	1962	2001	2021
Longueurs réelles du cours d'eau (km)	9,96	9,65	9,26	9,26
Longueur à vol d'oiseau	3,43	3,42	3,40	3,40
Indice de sinuosité	2 ,90	2,82	2,72	2,72
Longueur d'onde moyenne des méandres (m)	457,8	452	432,6	430
Amplitude moyenne des méandres (m)	480	487	476	470,8

Tableau 1 . Morphométrie des méandres du Bas Mikkès

a.- Période avant mise en place du barrage :

— L'état de l'oued en 1942 : sur la carte topographique de Béni Ammar à échelle de 1/50000, le tracé du Bas Mikkès correspondait en 1942 à un chenal unique avec des successions des méandres très sinueux, avec une sinuosité très forte de l'ordre de 2,90 ; sa longueur réelle était de 9,96 km.

— L'état de l'oued en 1962 : on a utilisé des photos aériennes à l'échelle de 1/25000 ; celles-ci montrent que le lit du Bas Mikkès présentait un style fluvial à chenal unique sinueux, avec une sinuosité de l'ordre de 2,82 et de de 9,65 km de long.

b.- Période après mise en place du barrage :

— L'état de l'oued en 2001 : on a exploité les images satellitaires de Google Earth du mois de février, 2001. Le Bas Mikkès avait un chenal unique également méandriforme, avec un indice de sinuosité égal à 2,72 Sa longueur était de 9,26 km.

— L'état de l'oued en 2021 : le Bas Mikkès n'a pas changé de style ; il a gardé le même style méandriforme, la même longueur de 9,26 km et le même indice de sinuosité.

La comparaison des quatre situations (fig.2), nous a permis de constater que :

— avant la mise en place du barrage, durant les années 1942, 1962, le tracé de l'Oued Mikkès qui fonctionnait dans des conditions naturelles, a subi des modifications et des migrations latérales significatives de son chenal. Ce qui est bien visible surtout pour les méandres de la partie amont, qui ont tendance à migrer latéralement vers la rive droite.

Après la mise en service du barrage, l'analyse diachronique de la période de deux décennies (2001-2021) montre que le lit de Mikkès était peu mobile, sans modifications morphologiques significatives. Cette situation est à mettre en rapport avec la mise en place du barrage Sidi Chahed qui a privé l'oued de ses apports liquides et solides naturels depuis 1997. Après avoir analysé l'impact du barrage Sidi Chahed sur la morphologie et la mobilité de l'Oued Mikkès, il est également essentiel d'examiner ses effets sur l'évolution de la largeur du lit mineur. En effet, les modifications hydrologiques et sédimentaires induites par le barrage ne se limitent pas aux changements du tracé et de la dynamique fluviale ; elles influencent également la configuration transversale du cours d'eau.

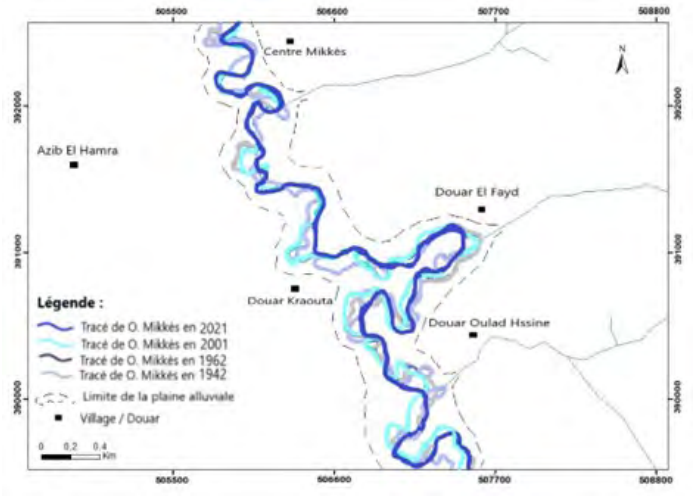


Figure 2 . Evolution du tracé du lit de Mikkès en aval du Barrage Sidi Chahed entre 1962 et 2021

3.2. Ajustement de la Largeur du Lit Mineur

Le barrage a un impact significatif sur la largeur du lit mineur, influençant à la fois la dynamique sédimentaire et l'écoulement hydrologique. En retenant les sédiments en amont, il réduit la charge solide transportée en aval, ce qui peut entraîner une incision du lit et une diminution progressive de sa largeur (G.M.Kondolf, 1997). De plus, la modification des débits, notamment la réduction des crues, limite l'érosion latérale et la mobilité des bancs alluviaux, favorisant ainsi une stabilisation ou un rétrécissement du lit mineur (S.A.Brandt, 2000). Ces transformations morphologiques peuvent avoir des répercussions écologiques importantes, notamment sur la biodiversité aquatique et riparienne (G.E.Petts et *al.*, 2005). Depuis la construction du barrage Sidi Chahed, en plus des modifications mentionnées ci-dessus, le lit fonctionnel de Mikkès a connu une importante réduction de sa largeur. Cette réduction est due en grande partie à la modification du rythme hydrologique de l'oued à l'aval du barrage, en particulier l'écrêtement de crues exceptionnelles qui façonnaient auparavant un lit plus large. L'analyse comparative des photographies aériennes de la mission 1962 et des images satellitaires Google Earth, 2021 (Fig.3) et (ph.2), nous a permis d'évaluer les modifications de la largeur moyenne du chenal qui a subi une réduction de plus de 40%, passant de 23,2 m en 1962 à seulement 13m en 2021. L'observation de terrain montre que le rétrécissement du lit fonctionnel est accompagné d'un enfoncement vertical. Ainsi, la réduction de la largeur du lit mineur s'inscrit dans un processus plus large de transformation des caractéristiques physiques du lit fluvial. Cette évolution ne se limite pas uniquement aux dimensions du chenal, mais affecte également la nature et la distribution des matériaux alluviaux qui le composent.

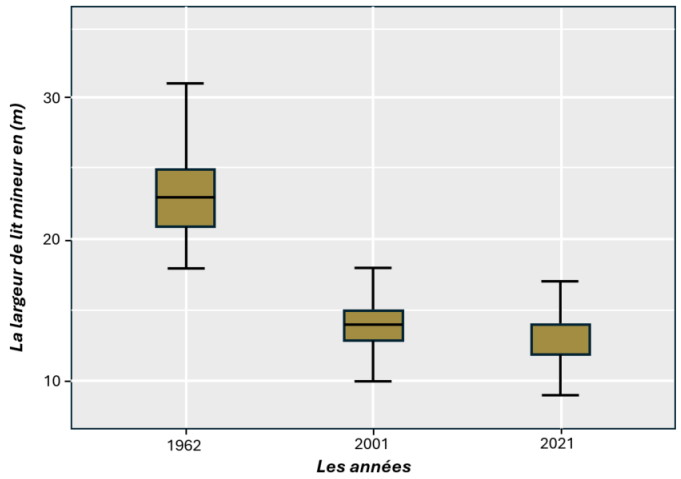


Figure 3 . Evolution la largeur moyenne du lit mineur du bas Mikkès entre 1962 et 2021

3.3. Impacts sur les Caracteristiques du Materiel Alluvial

L'effet des barrages sur les sédiments en transit est indirect, car il résulte d'une modification des conditions hydrauliques due à la présence d'une retenue en amont et à l'altération des caractéristiques hydrologiques en aval du barrage (I. El Ghalmi, 2023). De manière générale, les barrages limitent les apports sédimentaires et contribuent au déficit global en sédiments (F. Kotti et al., 2018). Les observations de terrain montrent que les dépôts actuels du lit fonctionnel en aval du barrage sont majoritairement constitués de sédiments de faible dimension, comparés aux sédiments alluviaux de la plaine alluviale. L'analyse granulométrique de prélèvements réalisés sur trois barres alluviales du lit fonctionnel (Fig. 4) révèle une prédominance de sédiments fins, avec des classes granulométriques inférieures à 40 mm de diamètre représentant entre 81 % et 86 %. Toutefois, des passages graveleux ou des petits galets sont parfois observés localement. Ces résultats traduisent une charge sédimentaire fine à dominante sablo-limoneuse, transportée principalement par les lâchers du barrage, l'érosion des sols limono-argileux des berges et le sapement des versants marneux environnants. L'obstacle formé par le barrage de Sidi Chahed en amont a considérablement réduit le transit des matériaux grossiers à galets provenant du Haut et du Moyen Mikkès. Ainsi l'abondance des matériaux fins reflète l'impact des submersions de la retenue sur l'espace fluviatile. En période de forte hydrologie, la remontée des eaux bloque les crues, réduisant la vitesse du courant et favorisant le dépôt des fractions fines (argiles, limons, sables) au détriment des particules grossières. Ainsi, une sédimentation d'aggradation fine progresse aval-amont au rythme de la remontée des eaux.

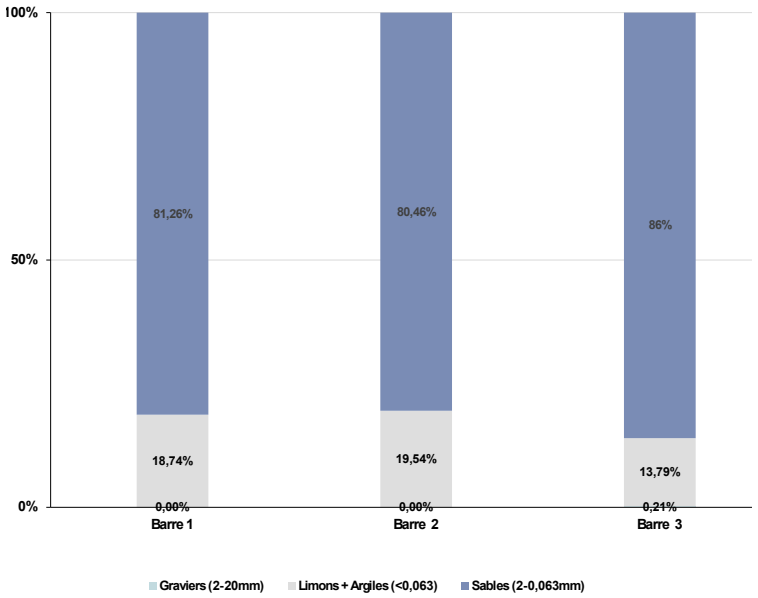
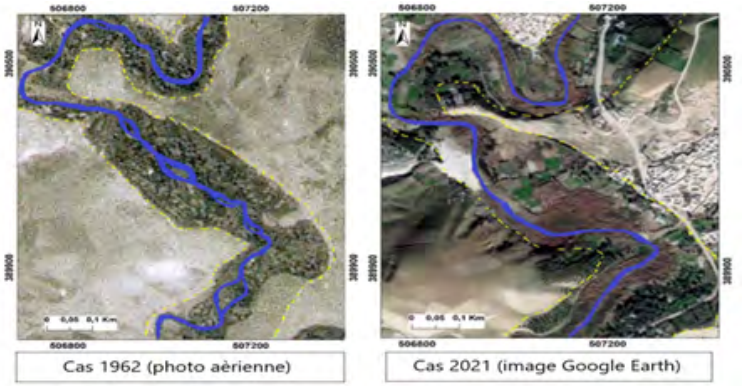


Figure 4 . Granulométrie des sédiments fins des lits mineur de la basse vallée de l'oued Mikkès

Conclusion

Le barrage de Sidi Chahed, installé il y a plus de deux décennies, a entraîné des changements significatifs dans les conditions hydrodynamiques de la basse vallée de l'Oued Mikkès, avec des répercussions morphologiques et sédimentologiques majeures. Ces ajustements, dus aux contraintes du barrage et de sa retenue, se sont traduits par une réduction de la largeur du lit de l'oued et des modifications des paramètres morphométriques, tels que la longueur d'onde et l'amplitude des méandres. Les processus sédimentaires naturels ont été affectés par le dépôt progressif de fines particules dans le lit fonctionnel, modifiant ainsi sa structure et ses caractéristiques hydrodynamiques. Ces transformations des morphologies fluviales dans la vallée du Bas Mikkès risquent d'avoir des impacts négatifs sur l'environnement et l'écologie locale. Pour atténuer ces effets, il est crucial de mettre en place une gestion durable du cours d'eau, incluant des lâchers d'eau contrôlés pour restaurer la dynamique fluviale, un suivi continu des évolutions morphologiques et sédimentaires, ainsi que des actions de stabilisation des berges par végétalisation. L'implication des populations locales et la sensibilisation à une gestion responsable des ressources en eau sont également essentielles pour garantir un équilibre entre les besoins humains et la préservation de l'environnement.À long terme, des recherches approfondies sur l'évolution hydrologique, l'impact sur la biodiversité et le développement de modèles prédictifs permettront d'anticiper les transformations du cours d'eau. Cette approche intégrée assurerait une gestion plus résiliente et durable de l'Oued Mikkès face aux défis posés par le barrage Sidi Chahed.



Photos 2 . Montrant la morphologie du lit de l'Oued Mikkès aval dans le secteur du Centre Mikkès, avant et après la mise en place du barrage Sidi Chahed.

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Sustentabilidade ambiental e o papel do ensino superior: um estudo de caso do rio Tapajós, na Amazónia

Environmental Sustainability and the role of Higher Education: a case study of the Tapajós River in Amazon

Luís Alipio Gomes
Tânia Suely Azevedo Brasileiro
Helana Miranda da C. Gomes

Resumo

Este estudo analisa a degradação ambiental do rio Tapajós, na Amazónia brasileira, com foco na contaminação por mercúrio associada ao desmatamento e à mineração artesanal. Examina a literatura científica sobre esses impactos e discute o papel das universidades na promoção da sustentabilidade socioambiental. As instituições de ensino superior têm papel essencial na formação de conhecimentos, valores e práticas voltadas à consciência ambiental, ao desenvolvimento sustentável e ao envolvimento comunitário na região amazónica.

Palavras-chave: Amazónia; Rio Tapajós; Contaminação por mercúrio; Ensino superior; Sustentabilidade ambiental.

Abstract

This study examines the environmental degradation of the Tapajós River in the Brazilian Amazon, focusing on mercury contamination linked to deforestation and artisanal mining. It analyzes the scientific literature on these impacts and discusses how universities can promote socio-environmental sustainability. Higher education institutions play a key role in shaping knowledge, values, and practices that contribute to environmental awareness, sustainable development, and community engagement in the Amazon region.

Keywords: Amazon; Tapajós River; Mercury contamination; Higher education; Environmental sustainability.

Luís Alipio Gomes
Tânia Suely Azevedo Brasileiro
PGEDA, Universidade Federal do Oeste do Pará, Pará, Brasil
Helana Miranda da C. Gomes
Grupo de Estudos e Pesquisa Praxis, Universidade Federal do Oeste do Pará, Brasil

0000-0002-6791-9244
0000-0002-8423-4466
0000-0002-7393-8679

Introduction

Environmental issues, such as water pollution and contamination, degradation, crises of natural resources, energy, and food, highlight what is recognized as a civilizational crisis (Leff 2002). The Amazon is one of the ecosystems most affected by this crisis, with noticeable impacts on agriculture, biodiversity, human health, and water quality (Buckeridge 2008). It is no coincidence that Goal 6 of the United Nations (UN) Sustainable Development Goals (SDGs) addresses "Clean Water and Sanitation." Specifically, Target 6.6 states that, by 2020, ecosystems related to water including mountains, forests, wetlands, rivers, aquifers, and lakes should be protected and restored.

In 2022, an aerial image of the Tapajós River, located in the Northern Region, State of Pará, Brazil, gained significant regional and international attention. The waters of the Tapajós River have long been recognized for their blue-green hue, a characteristic even celebrated in the anthem of the municipality of Santarém. The anthem poetically compares the river's waters to the blue color of the sky, a homage to the beauty of the Tapajós River. But why did this aerial image draw so much attention? The image clearly revealed a striking change in the color of the Tapajós River, particularly near an internationally renowned tourist attraction, the beach of Alter do Chão (Figure 1). The waters were no longer blue or emerald green. Instead, the Tapajós River's water resembled the muddy color of the Amazon River.

The mosaic of information and news associated various potential causes for this phenomenon, ranging from the presence of algae to deforestation and illegal gold mining activities.

Figure 1. Difference in the coloration of the Tapajós River
Available at: https://o-boto.com/blog/cor-alterada-no-rio-tapajos-reflexoes-sobre-o-aumento-da-turbidez-e-suas-possiveis-causas. Access: 1/5/2025.

Faced with the various explanations regarding the causes and consequences of this phenomenon, one point was consensual: the waters of the Tapajós River were different; their coloration was no longer the same. In summary, beyond seeking an explanation, urgent measures needed to be taken. Thus, it is important to ask: considering the risk to the water resources of the Tapajós River, what does the scientific literature say about its current condition? Could the change in water coloration be associated with anthropogenic activity? If so, what type(s) of activities have been the primary drivers of this phenomenon? Furthermore, what role do higher education institutions located in the Amazon play in relation to the water resources of this region, and how can they contribute to the training of professionals (bachelor's and licentiates) aligned with environmental sustainability?

These questions guide the organization, systematization, and presentation of this study, which seeks to discuss the relationship between universities and environmental sustainability.

Methodology

A qualitative research approach was adopted, utilizing bibliographic research that included scientific articles. The studies, research and participation in an international research group called Climate U made it possible to carry outr the

approach about Environmental Sustainability and the role of Higher Education. To research about a case study of the Tapajós River in the Amazon the following databases were selected: Web of Science, ScienceDirect and SCOPUS. The search string were: "water" AND "mercury" AND "Rio Tapajós". There was no limit of time for publication. The question to motivate the research were: what does the scientific literature say about pollution of Tapajós River? Could the change in water coloration be associated with anthropogenic activity?

Results And Discussion

It was identified 4 articles in SCOPUS, 1 article in Web of Science, 15 articles of 23 of ScienceDirect. The titles, abstracts related to the theme of this research were considered.

Tapajós River: the announced contamination

One of the main pollutants impacting the Tapajós River Basin (Figure 2) is mercury (Hg), a metal that naturally exists in Amazonian soils (Patry *et al*. 2013).

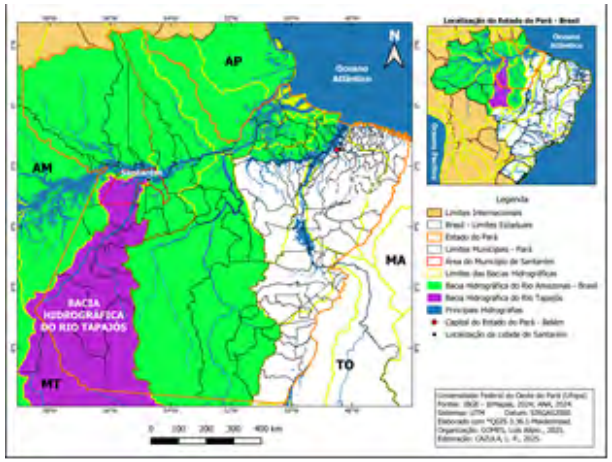

Figure 2. Tapajós River Basin. Publishing: CAZULA. L.P., 2025

The deforestation that drives erosive processes leads to an increase in the transfer of mercury from the soil to aquatic ecosystems (Farella *et al*. 2001). The severe soil erosion along the banks of the Tapajós River causes multiple imbalances in the aquatic ecosystem, such as increased water turbidity and organic matter deposition, among others (Farella *et al*., 2001; Berzas Nevado *et al*. 2010)). Once water is contaminated, fish consumption becomes a vector for mercury proliferation among humans (Maurice-Bourgoin *et al*. 2000). The population of small communities along the Tapajós River relies on fish as their primary source of animal protein. Since 1992, studies have confirmed that mercury contamination in fish consumed in the region (Carvalho Da Silva et al. 2022; Pinheiro et al. 2000).

In addition to the impacts of deforestation, another factor contributing to the contamination of the Tapajós River Basin is the intensification of artisanal mining activities. Artisanal and small-scale mining has been widely practiced in the Amazon and provides income for approximately 35,000 workers in the Tapajós region of Pará, Brazil. These workers are commonly referred to as "garimpeiros" (Junior e Carvalho 2023). Studies indicate that the uncontrolled use of mercury (Hg) in artisanal gold extraction has released thousands of tons of mercury-contaminated waste into the Amazon biome (Meneses *et al*. 2022). The disposal of this material has not only degraded water quality but also affected the quality of life of people living in the riverside communities of the Tapajós basin, as well as urban populations (Meneses *et al*., 2022). For decades, populations in Amazonian communities have been consuming mercury-contaminated fish, as confirmed by several studies.

The consumption of contaminated fish has also been identified as a potential risk for the onset of symptoms of Minamata disease (Pinheiro *et al*., 2000). Even populations living far from gold mining sites are impacted, whether through fish consumption, atmospheric emissions, deforestation, or the disturbance of

river sediments, which contribute to mercury release into the environment (Roulet *et al.* 1998). These factors provide some explanations for the observed changes in the coloration of Tapajós River waters. Other sources suggest that, in addition to mining activities, increased turbidity may result from a higher presence of algae, sediment runoff due to soil erosion in the basin's tributaries – driven by deforestation for logging, agriculture, and livestock – soil disturbance, chemical substance disposal, and potential tailings dam overflows during the flood season.

Given this chaotic scenario, what can be done to mitigate these environmental impacts and address the risks of water contamination in the Amazon? The answer is neither simple nor straightforward. Research suggests that mitigating mercury contamination affecting local populations requires the implementation of a health surveillance program (Meneses *et al.*, 2022) or maintaining an epidemiological surveillance program (Pinheiro *et al.*, 2000). A medium- and long-term solution lies in investing in the initial and continuing education of professionals who acquire socio-environmental knowledge, values, and attitudes through their training, promoting best practices. The university, as a strategic locus for this training, will be addressed next.

The university and its commitment to environmental sustainability

A theoretical framework supports the importance of higher education in addressing sustainable development. The rationale for this is deeply rooted in the identity of higher education itself, which has been emphasized over the last millennium. According to Mello (2011) higher education became a priority concern for funding agencies and governments at the beginning of the millennium. The 1998 UNESCO World Conference in Paris, involving approximately 5,000 participants from 182 countries, affirmed higher education as both public good and a public service. Considering that capitalism has undergone a long process of restructuring, this transformation has profoundly impacted universities through:

> "a vast, dense, and even unpredictable agenda of fundamental changes in higher education systems... involving, among other initiatives: diversification in the provision of education; degree titles; curriculum reform; changes in legal frameworks; innovations in teaching technologies; reform of governance structures; adjustments in statutes and faculty careers; methodologies and teaching modes; changes in funding and academic planning systems; creation of accreditation systems compatible with international quality requirements; establishment of new institutional evaluation parameters, and other measures – all to adapt higher education institutions (HEIs) to the new demands of flexibility, universality, efficiency, and competitiveness in the dynamic and interactive landscape of the global economy" (Mello, 2011, p. 33-34).

In the context of 21st-century higher education, it is essential to critically analyze what this reality means for the role of universities. Cunha and Leite (1996) question whether the university's purpose is limited to maintaining isolated professional careers, preparing individuals for a predetermined societal model, or merely reproducing social relations. They argue for revitalizing teaching and learning within universities as a continuous concern, coupled with the pursuit of scientific knowledge aimed at fostering more just societies.

University education should not simply cater to labor market demands. If it did, the university's role could be reduced to training rather than educating (Coelho & Furtado 2016). Academic life gains meaning when it expands and deepens the cultural and human horizons of faculty and students by distinguishing "the necessary from the contingent, the permanent from the mutable, the essence from the appearance, the essential from the accessory, the individual and specific from the general and universal" (Coelho & Furtado, 2016, p. 101). While the university is not the sole vector for this expansion, its contribution

is significant.

In the context of sustainability, a course, curriculum, or professional training is not merely a collection of subjects and syllabi. Instead, it represents a structured effort in reading, systematic study, teaching, understanding, questioning the sense and origin of the world, human actions, society, knowledge, integral education, and the university itself. As a formative institution, the university must prioritize the pursuit of knowledge and the recognition of ancestral wisdom through a dialogical process, challenging the physical and social world, inspired by Plato and Aristotle's admiration, René Descartes' methodical doubt, and Husserl's rigor in thinking and learning. This approach necessitates "forming and self-forming, cultivating the vibrant and provocative knowledge of sensitivity, imagination, intelligence, thought, and action among students and professors" (Coelho & Furtado, 2016, p. 103). In summary, it is the responsibility of this millennial institution the university:

> "[...] to work so that undergraduates and postgraduates, at different levels, dedicate themselves to study and education, enabling them to participate in the creation of new forms of collective and personal life, and professional practices aligned with autonomy, freedom, equality, fraternity, and democracy, which, however, only exist in a relationship – often uneasy – with others" (Coelho & Furtado, 2016, p. 102-103).

It is understood that individuals with university education are more receptive to engaging in actions directed towards environmental sustainability. This is primarily due to the projective function of higher education institutions, which aim to disseminate a set of values in students' lives (McCowan 2022). However, this function is not restricted to the classroom. The academic community comprising professors, students, and staff – conducts activities in their areas of operation that impact nature and the environment, whether through the production of solid waste or carbon emissions.

This indicates that the dissemination of values must reach the various sectors that comprise the institution as a whole, both internally and externally. Externally, universities provide services to organizations through consulting work, project execution, and direct interaction with the community. These are typically identified as extension activities, research initiatives, or scientific collaborations. These external stakeholders are also influenced by universities and act as "impact drivers for society as a whole" (McCowan, 2020a, p. 10).

In the academic context, several authors have conducted research and published works on this subject (Brasileiro et al. 2023; Caeiro et al. 2013; Gomes & Brasileiro 2018; ROLLESTON et al. 2023). Rolleston *et al.* (2023) argue that universities influence students' practices, attitudes, and knowledge, primarily through their teaching.

Figure 3 highlights how the university environment – committed to environmental sustainability – through teaching, research, extension, and governance, exerts influence on society as a whole. Education for sustainability helps maintain a level of environmental awareness, preventing deforestation and preserving the forest. This process generates impacts on the biosphere, particularly in terms of conservation and preservation. Conversely, there is also a reverse process – from society to the university.

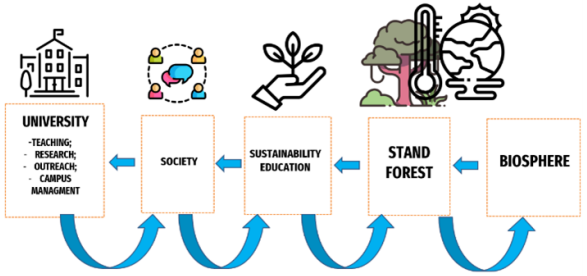

Figure 3. Levels of impact. Elaborated by the authors (2025).

Thus, universities need to strengthen their curriculum and pedagogy to more effectively achieve the desired outcomes. In

a survey conducted with students from universities in Fiji, Kenya, and Brazil, the results showed that students feel encouraged when their universities demonstrate a commitment to the environment. Researchers suggest that student learning in universities can form a virtuous cycle, creating opportunities for deeper learning, particularly on topics related to sustainability, while fostering student engagement in projects and campaigns on environmental issues (Rolleston *et al.,* 2023).

McCowan (2022) argues that teaching about sustainability in universities, such as addressing climate change, has become not only crucial but also inevitable. There is an understanding that education for sustainability fosters discussions about a new green agenda for teaching, based on the following approaches: skills for "green jobs"; skills or capacities to develop a "green" lifestyle focused on quality of life; and skills for a "green" transformation, which involve identifying oppressive structures in society (Kwauk, C. & Casey, O. 2021).

Regarding higher education and the Amazon, Gomes *et al.* (2022) emphasize that the implementation of this approach in universities can be achieved if the values of nature and land connectivity are prioritized by higher education institutions located in the Amazon. This is an indispensable condition for institutions in this region: to highlight and integrate into their teaching dimension research, extension, management, and discussions on sustainability. This is particularly important because the predatory culture of the "Western man," characterized by technical-scientific dominance, must be reconsidered. Sustainable education emerges as a viable strategy for re-educating humanity to value the Earth (Gadotti 2004).

Conclusion

Humanity has transformed planet Earth to such an extent that economic activities have caused significant social, economic, and environmental impacts. It is essential not to lose sight of the need for change, particularly in a society marked by consumerism within a capitalist system. As Senegalese ecologist Babia Dioum states, "In the end, we will conserve only what we love. We will love only what we understand. We will understand only what we are taught" (Frisk e Larson 2011:2).

The rivers of the Amazon, such as the Tapajós River, have been the subject of numerous reports due to changes in the color of their waters. A recurring question arises: what should be done in this situation? Sanitary and epidemiological measures are necessary; however, "no institution in modern society is better positioned, and none is more obligated to facilitate the transition to a sustainable future than colleges and universities" (Orr 2002:96).

In this context, it is crucial to develop a socio-environmental sustainability policy with integrated actions in teaching, research, outreach, and management at higher education institutions located in the Amazon region. It is equally important to intensify and/or create initiatives that promote sustainability in university curricula across undergraduate and graduate programs, which are responsible for training human resources who will act in this region or anywhere on the planet whether as professionals in various fields or as policymakers.

Finally, universities located in the Amazon, regardless of their programs or fields of knowledge, must adopt interdisciplinary approaches and innovative teaching methods to train professionals with a focus on socio-environmental sustainability.

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Suscetibilidade e exposição à erosão costeira no município de Peniche – evolução recente e futura

Coastal Erosion Susceptibility and Exposure in the Municipality of Peniche – Recent and Future Evolution

Bernardo Sales
Sérgio C. Oliveira
Jorge Trindade

Resumo

Este estudo avalia a evolução recente (2008–2023) e projetada da linha de costa de Peniche, combinando modelação de suscetibilidade a movimentos de vertente com a análise da evolução costeira através do DSAS. Os resultados evidenciam recuo significativo nos setores Gambôa – Baleal e Azenhas e pequena acreção em Molhe Leste – Consolação. O setor Baleal – Pico da Mota apresenta maior suscetibilidade à erosão. Apesar da reduzida exposição atual, recomenda-se monitorização contínua e modelos preditivos mais robustos para apoiar a gestão e o ordenamento costeiro.

Palavras-chave: Erosão costeira; Peniche; Suscetibilidade de arribas; Evolução da linha de costa; Gestão costeira.

Abstract

This study assesses the recent (2008–2023) and projected evolution of the Peniche coastline, combining logistic regression modeling of cliff landslide susceptibility with shoreline change analysis using DSAS. Results show significant retreat in the Gambôa – Baleal and Azenhas sectors and minor accretion in Molhe Leste – Consolação. The Baleal – Pico da Mota sector exhibits the highest cliff erosion susceptibility. Although current exposure of residential areas is low, monitoring and improved projection models are essential for future coastal risk management and land-use planning.

Keywords: Coastal erosion; Peniche; Cliff susceptibility; Shoreline change; Coastal management.

Bernardo Sales
Instituto de Geografia e Ordenamento do Território, University of Lisbon, Portugal
Sérgio C. Oliveira
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Associate Laboratory Terra, University of Lisbon, Portugal
Jorge Trindade
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Centre for Global Studies, Universidade Aberta, Lisbon, Portugal

0000-0001-7428-0402
0000-0003-0883-8564
0000-0001-5610-5942

Introduction

The recent evolution of the coastline, marked by sediment deficits, intense coastal erosion, and intensive or uncontrolled development of these areas, is one of the main issues that, must be understood for better, improved, and more effective coastal management and risk reduction. This is due to the dynamics of sandy systems or susceptibility to slope movements on cliffed coastlines.

On the cliff rocky coastlines, erosion mainly begins with the wear of the base, resulting in erosion due to undercutting, eventually leading to retreat. Cliff evolution also includes subaerial processes, which often cause erosion due to the instability of coastal cliffs, and processes related to hydraulic erosion, especially surface runoff, both concentrated (e.g., gullying and rill erosion) and un-concentrated. On the sandy coastline, erosion depends on the balance between sediments deposited and those transported by the sea, which, in turn, are influenced by natural and anthropogenic factors operating at various spatial and temporal scales, involving several processes, some of which are related to wave propagation to the shoreline (e.g., transformation processes: refraction, diffraction, dissipation, collapse, among others) (Trindade, 2010).

The study area (Figure 1), is located in the municipality of Peniche, and consists of both sandy and rocky coastlines. The sandy coastline contains beach-dune and beach-cliff systems. The rocky coastline is predominantly composed of limestones and marls, with systems such as abrasion platforms cliffs, block cliffs, and a mixed system that corresponds to the abrasion platform with blocks and a submerged cliff system that is in direct contact with the sea. Both types of coastline, sandy and rocky, contain geomorphologically interesting features such as the tombolos of Baleal and Peniche.

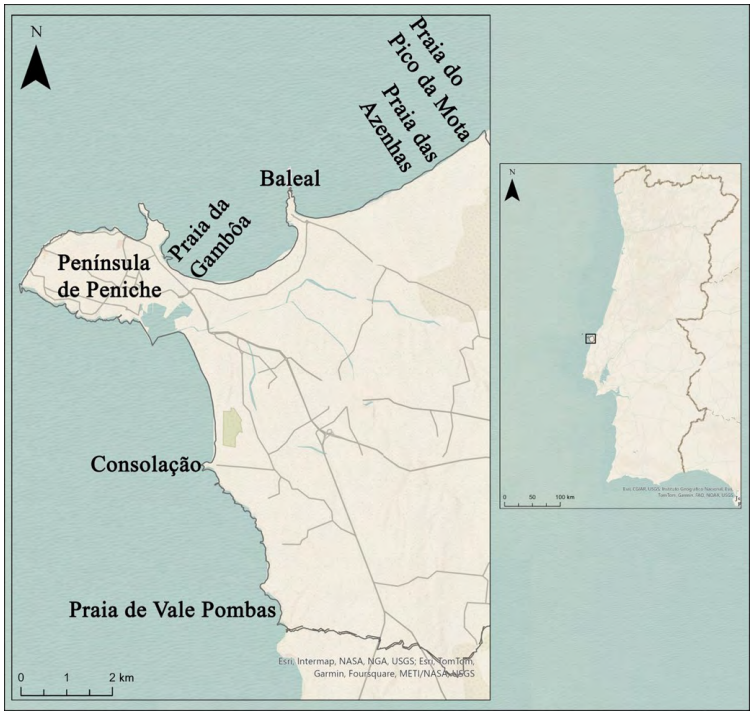

Figure 1. Geographic context of the coastline in the municipality of Peniche.

The study of coastal erosion, dynamics, and the evolution of the sandy coastline in Peniche (or covering larger areas, but including Peniche) has been developed by several authors in recent decades, which proves the relevance of the topic and study area. Examples of work on the sandy coastline include studies by Silva et al. (2013a,b,c), Ponte Lira et al. (2016), and for the rocky coastline, the works of Marques (1998), Penacho and Marques (2023). In this regard, the work to be carried out aims to continue studies on this topic, focusing on the assessment of the recent and future retreat of the coastline, considering the diversity of sandy and rocky systems present in the coastline of the municipality of Peniche, to identify and map the variation in the position of the coastline and exposure to coastal erosion.

Methods

The susceptibility to landslides on the rocky coastline was evaluated using the statistical method of logistic regression. This method allows for the estimation of the probability associated with the occurrence of landslides based on a set of independent explanatory variables, and is used in situations where the dependent variable is dichotomous in nature (0 – 1: absence – presence). This method has been applied in the assessment of landslide susceptibility in cliff coasts and non-coastal slopes, by various authors both internationally (Dai et al., 2001; Brahim & Elmoulat, 2018) and in Portugal (Marques et al., 2013; Marques, 2018; Queiroz & Marques, 2019; Penacho & Marques, 2023). Landslide susceptibility modelling was performed using IBM SPSS Statistics v29 software and an independent cross-validation process to train the final susceptibility model, this process was repeated five times, with the final model being the average of the five susceptibility models produced.

The study regarding coastline evolution began with the selection of an appropriate coastal indicator. This indicator must be suitable for the temporal scale of the study, which in this case is medium-term (2008-2023). To ensure consistent measurement, the chosen indicator should be as independent as possible from frequent changes in water levels and the seasonal morphological cycle of the beach. Thus, the vegetation line indicator was chosen for the sandy coastline, as most of the sandy coastline consists of dunes bounded by vegetation, and due to the difficulty of precisely identifying the foot of the dune from aerial photographs. For the rocky coastline, the cliff crest was considered as the indicator, as it is easily identifiable through photointerpretation. The coastline line for the sandy coastline was delineated for the years 2008, 2015, and 2023. For the rocky coastline, only the years 2008 and 2023 were considered. The rates of coastline evolution were calculated using GIS with the Digital Shoreline Analysis System v6.0.168 (DSAS) tool (Himmelstoss et al., 2024).

Based on the evolution rates obtained from the previous method, a linear projection of the coastline was made. The projection was carried out for a future scenario of 15 years, as the evolution rate data acquired in this study also correspond to a period of 15 years (2008–2023). In applying this projection, all values related to accretion (+0) were considered to be in dynamic equilibrium. Thus, the retreat value obtained for each terrain unit (TU) corresponds to the evolution rate (ER) of each TU, multiplied by the time period (TP) for which the projection is to be made, which in this case is 15 years (TP15). The equation is given by: $TP15 = ER * 15$.

This projection was made in an exploratory manner due to a lack of data and time to create a robust model of coastline position evolution for future scenarios. It is a simple linear projection based on the evolution rates recorded in the present, assuming that the trends observed in the last 15 years will remain similar to those expected for an equal period in the future. This assumption is valid as long as no significant changes in the conditions that govern coastal erosion in the study area occur in the short term. This projected short-term trend may be biased by the dynamics present in the sandy coastline, and thus the use of these trends is accepted, assuming their exploratory nature.

Based on the observed average retreat value for each terrain unit and coastline retreat projections, a landwards future position of the coastline was created for each TU, thus allowing for the evaluation of whether the expected coastline retreat could have any impact on existing residential infrastructure.

Results

In this study, 149 landslides were identified, resulting in a loss of cliff surface area of approximately 9,028 m². Spatially, these landslides are predominantly clustered in the Baleal – Praia Pico da Mota section, where 142 landslides are present. The remaining 7 are located in the Consolação – Praia de Vale Pombas section.

One of the reasons for this low number of occurrences is a series of anthropogenic interventions aimed at mitigating the occurrence of geomorphological instability manifestations in this sector, including the presence of hexagonal grids and protection through the application of sprayed concrete. No landslides were observed in the Peniche Peninsula sector during the study period.

The final susceptibility map for landslides in coastal cliffs, as mentioned earlier, resulted from the integration of the five landslide susceptibility models produced. The area under the curve (AUC) values for each model are represented in Table 1. The final susceptibility score is defined by the average value of the scores obtained for each TU across the five previously defined susceptibility models. This approach allows for independent cross-validation of each susceptibility model and, by using all TUs with occurrences, enhances the predictive capacity of the final susceptibility model.

Model	AUC
Model 1	0.632
Model 2	0.833
Model 3	0.830
Model 4	0.878
Model 5	0.731

Table 1. AUC values of each slope movement susceptibility assessment regression model on coastal cliffs.

In the final susceptibility model (average of the five models), it was observed that the most susceptible sector is the Baleal – Praia do Pico da Mota stretch, where the very high and high susceptibility classes predominate, it is also in this sector where the highest number of landslides occurred. In the Peniche Peninsula sector, as mentioned earlier, no landslides were observed (none were identified) during the study period (2008-2023). This record confirms the predominance of the class corresponding to low and very low susceptibility. The last sector corresponds to the Consolação – Praia de Vale Pombas stretch, where only 5 terrain units were affected by landslides. As also mentioned earlier, this sector is heavily protected from erosion by a series of (preventive) interventions aimed at limiting landslide occurrences. Therefore, some of the TUs with no landslide occurrences but classified with high susceptibility may require additional monitoring.

The study of the coastline evolution over the last 15 years (2008-2023) revealed a strong erosive trend on the sandy coastline in the Praia das Azenhas and Praia da Gambôa – Praia do Baleal Sul sectors, with the latter stretch being particularly severe. In contrast, in the Praia do Molhe Leste – Praia da Consolação sector, accretion values were observed, although they were very insignificant, as shown in Table 2.

Sector		2008 - 2015	2015 - 2023	2008 - 2023
Praia das Azenhas	**Coast Change Rate (m/year)**	-0,03 ± 0,14	-0,30 ± 0,17	-0,18 ± 0,10
	Total Coast Change Rate (m)	-0,21	-2,4	-2,7
Praia da Gambôa – Praia do Baleal Sul	**Coast Change Rate (m/year)**	-1,37 ± 0,14	-1,25 ± 0,17	-1,32 ± 0,10
	Total Coast Change Rate (m)	-9,59	-10	-19,80
Praia do Molhe Leste – Praia da Consolação	**Coast Change Rate (m/year)**	-0,21 ± 0,14	0,26 ± 0,17	0,05 ± 0,10
	Total Coast Change Rate (m)	-1,47	2,08	0,75

Table 2. Average yearly and total evolutionary trend for the sandy coastline.

In the rocky coastline (Table 3), the sector with the greatest retreat was the Praia das Azenhas – Praia do Pico da Mota sector, where a total retreat value of 3 m was recorded, followed

by the Consolação sector with a total retreat of 1.35 m. Lastly, the Baleal – Praia das Azenhas sector showed a total retreat of 0.3 m.

Sector		2008 - 2023
Praia do Baleal Norte – Praia das Azenhas	Coast Change Rate (m/year)	0,02 ± 0,08
	Total Coast Change Rate (m)	0,3
Praia do Baleal Norte – Praia das Azenhas	Coast Change Rate (m/year)	0,02 ± 0,08
	Total Coast Change Rate (m)	0,3
Praia das Azenhas – Praia do Pico da Mota	Coast Change Rate (m/year)	0,20 ± 0,08
	Total Coast Change Rate (m)	3
Consolação	Coast Change Rate (m/year)	0,09 ± 0,08
	Total Coast Change Rate (m)	1,35

Table 3. Average yearly and total evolutionary trend for the rocky coastline

Based on the evolution values present in Table 2 and assuming that the conditions governing erosion in these sectors will not change significantly compared to those observed in the last 15 years, an average retreat of 17.20 m is expected in the Gambôa – Baleal sector, 2.02 m in the Molhe Leste – Consolação sector, and 7.08 m at Praia das Azenhas.

The same process was applied to the rocky coastline, resulting in an expected average retreat of 1.55 m in the Baleal Norte – Pico da Mota sector, and an average retreat of 0.16 m in the Consolação – Vale Pombas sector. Although these values do not represent a highly pronounced erosive trend, they should not be underestimated, as they may occasionally correspond to more significant retreats associated with the occurrence of larger magnitude slope movements.

Regarding exposure in the study area, mainly due to the extent of the dune system, no TU in the sandy coastline was found to have residential buildings within the expected retreat zone. In the rocky coastline, two situations were identified that may jeopardize the stability of certain buildings, as the expected retreat includes some urban fabric, particularly part of a parking lot and the wall/fence of a property/residence. Although no housing is directly affected, the proximity to slope movements observed in recent years, combined with the expected retreats, could undermine the stability of the cliff in the short/medium term, potentially affecting the housing itself. Therefore, there is a need to monitor this sector.

Conclusion

In conclusion, the results obtained point to retreat values related to recent coastal erosion in the rocky coastline sector, Baleal – Praia do Pico da Mota, and in the sandy coastline sectors, Gambôa – Baleal and Praia das Azenhas. The sandy sector Molhe Leste – Consolação stands out as the only sector with accretion values, although these are not significant. The Peniche Peninsula (rocky coastline) emerges as the least susceptible sector to coastal erosion during this study period (2008-2023).

The assessment of susceptibility to erosion is essential in studies addressing the coastline, as it helps identify the most critical sectors to be considered in future land-use planning.

For future studies, there is a particular emphasis on the need to apply a more robust coastline projection method that takes into account dynamics primarily related to erosion and coastal flooding, especially in sandy systems. This includes the use of different sea-level rise scenarios for the end of the century, storm surge, wave run-up, and other factors.

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Contributo de modelos estatísticos na avaliação da suscetibilidade a cheias na província de Essaouira, Marrocos

Contribution of statistical models in flood susceptibility assessment in Essaouira Province-Morocco

Abdellah Khouz
Jorge Trindade
Pedro Pinto Santos
Fatima El Bchari
Sérgio C. Oliveira
Ricardo A. C. Garcia
Asma Bougayou
Mustapha Ikirri
Mourad Jadoud
Said Rachidi
Blaid Bougadir

Resumo

As inundações são perigos naturais recorrentes nas regiões norte e central de Marrocos, causando perdas significativas. Este estudo desenvolveu um mapa de suscetibilidade a inundações nas bacias hidrográficas da província de Essaouira utilizando três modelos: Processo de Hierarquia Analítica (AHP), Razão de Frequência (FR) e Pesos de Evidência (WoE). Dez fatores condicionantes; declive, altitude, densidade de drenagem, precipitação, litologia e índice de umidade topográfica…, foram integrados num sistema SIG. A precisão dos modelos, avaliada pela área sob a curva (AUC), superou 90%, indicando alta fiabilidade. As zonas mais suscetíveis situam-se perto da cidade de Essaouira e do rio Ksob.

Palavras-chave: Susceptibilidade a inundações; Processo de Hierarquia Analítica (AHP); Modelo de Razão de Frequência (FR); Pesos de Evidência (WoE); Essaouira; Marrocos.

Abdellah Khouz
Jorge Trindade
Sérgio C. Oliveira
Ricardo A. C. Garcia
Centro de Estudos Globais, Universidade Aberta, Lisbon, Portugal
Centre of Geographical Studies, Institute of Geography and Spatial Planning, Universidade de Lisboa, Lisbon, Portugal
Pedro Pinto Santos
Centre of Geographical Studies, Institute of Geography and Spatial Planning, Universidade de Lisboa, Lisbon, Portugal
Fatima El Bchari
Polydisciplinary Faculty of Safi, Safi, Morocco, Department of Earth Sciences, Cadi Ayyad University, Marrakech, Morocco

Abstract

Floods are recurrent natural hazards in Morocco's northern and central regions, causing considerable losses. This study developed a flood susceptibility map for the Essaouira provincial watersheds using three models: Analytic Hierarchy Process (AHP), Frequency Ratio (FR), and Weights-of-Evidence (WoE). Ten conditioning factors; slope, elevation, drainage density, rainfall, lithology, and topographic wetness index…, were integrated within a GIS framework. Model accuracy, evaluated using the area under the curve (AUC), exceeded 90% for all methods, confirming their reliability. Highly flood-prone zones were mainly identified near Essaouira city along the Ksob River and surrounding rural centers.

Keywords: Flood susceptibility; Analytic Hierarchy Process (AHP); Frequency Ratio (FR); Weights-of-Evidence (WoE); Essaouira; Morocco.

Asma Bougayou
Blaid Bougadir
Higher School of Technology Essaouira, Laboratory of Applied Sciences for the Environment and Sustainable Development (SAEDD), Cadi Ayyad University, Marrakech, Morocco
Mustapha Ikirri
Geology Department, Faculty of Sciences, Université Ibn Zohr, Agadir, Morocco
Mourad Jadoud
Faculty of sciences El Jadida, Geosciences and Environmental Techniques Laboratory, Chouaïb Doukkali University, El Jadida, Morocco
Said Rachidi
High School of Technology-Salé, Mohammadia School of Engineers (EMI), Mohamed V University, Rabat, Morocco

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Introduction

Floods can cause indirect harm, including damage, to transportation systems, cultural landmarks, natural ecosystems, agriculture, bridges and the economy [1–4]. Additionally, floods lead to the loss of thousands of lives and the displacement of millions of people worldwide each year [5–8]. For flood analysis and mapping of flood areas, one popular model within the criteria analysis is the Analytic Hierarchy Process (AHP) method [9]. AHP involves an evaluation process that includes pairwise comparisons of parameters, ranking them accordingly to find the solution for a given problem [10–13]. The ratio (FR) method is an effective statistical technique with a simple yet comprehensible concept [14]. It enables the study of the impact of different factors on flooding occurrences [3,15]. Furthermore, while the weights of evidence (WoE) based method is commonly used for landslide mapping purposes, its application in flood modelling is new [16,17]. WoE utilizes the model for decision-making under uncertain conditions. This makes it suitable for hazard mapping as it considers uncertainties associated with hazard events and their relationships, with landscapes [18].

The Essaouira province in the western coastal region of Morocco has experienced severe flood occurrences in the past due to rapid urbanization. However, conducting an accurate assessment of flood susceptibility is a challenging process due to a lack of data and other obstacles. This paper aims to i) inventory the flood records and their conditioning factors, ii) elaborate susceptibility maps using the AHP model, FR model, and WoE model, and iii) validate the produced susceptibility maps and identify the most accurate one.

Materials and Methods

The study area under consideration in this research encompasses the province of Essaouira, located on the western side of the High Atlas mountains in Morocco [19], and covers an area of approximately 6,335 km^2. The methodology used in the research involved several steps to assess floods susceptibility in the Essaouira province. Firstly, an inventory of flooded points was created, followed by assessing several conditioning factors responsible for the occurrence of floods. The next step involved combining remote sensing and geospatial analysis, as well as the use of the AHP, FR, and WoE models to produce flood hazard potential maps, and the most accurate map was chosen. Field surveys and validation were used to support the preparation of the data sources used in the analysis.

Results

Flood inventory and conditioning factors

The province of Essaouira experienced flooding in the city of Essaouira due to the malfunctioning of the stormwater drainage system. Other floods, caused by water inputs from peri-urban basins surrounding the centers (particularly Smimou, Essaouira, Igouzoulene, Ksob, Mejji, Tamanar, and others), led to runoff that posed a threat to the safety of residents and their properties. The flood inventory map was divided into two subsets: 70% for training and 30% for testing, following the methodology suggested by Ohlmacher and Davis 2003 [20]. After preparing the dataset, each of the 10 conditioning factors was transformed into a grid spatial database of 12.5 × 12.5 meters. The grid covered the entire Essaouira Province with an area of 6,224 km^2[19].

Susceptibility modelling and validation

Analytic Hierarchy Process (AHP): After the application of weighting to all conditioning factors, the final flood susceptibility map was generated. The map was classified using the natural breaks (Jenks) grading method, as illustrated in Figure 1. In the context of the AHP method, this classification approach is considered the most suitable for delineating

flood susceptibility zones [18,19].

Regarding the distribution of flood susceptibility classes in area percentage, the lowest share was observed in the very high (0%) and very low (0.01%) classes. The high flood susceptibility class covers an area of 1.48%, while the low susceptibility class represents 31.84% of the study area. The largest share (66.67%) is attributed to the moderate flood susceptibility class.

Regarding the spatial distribution, the AHP analysis results indicate that no areas in the Essaouira province are classified as very highly susceptible to flood occurrence. However, there are areas with a high susceptibility to floods. These include Oued Ksob near Diabat village and Essaouira city, Guazoua village located in the south of Essaouira, Oued Tamanar, Oued Smimou, Had Dra village, and Souira Guedima city situated near the outlet of the major Tensift River.

Frequency ratio model (FR): Based on the results of the Frequency Ratio (FR) model, it was determined that 0.51% of the study area in the Essaouira province is categorized as having high to very high susceptibility to flood occurrence, using the Natural Breaks method for classification, which was consistently applied across all models. Conversely, over 96% of the province exhibits very low to low susceptibility to floods.

Analyzing the spatial distribution, the very high class, covering an area of 7 km^2, is distributed across several locations. This includes Essaouira city, where urban floods have been reported, Diabat Village located near the left limit of Ksob Oued, Smimou village, and the outlet of Ouazzi Oued. The high class, encompassing an area of 24 km^2, is primarily visible in Tafedna village along the Igouzoulen outlet, Tidzi and Had Dra villages, as well as the El Hanchane - Lagdadra communes situated in relatively flat areas. The remaining area, predominantly at higher altitudes and upstream of the watersheds, is occupied by the very low to low flood susceptibility classes.

Weights-of-evidence (WoE): In the previous section, all the parameters were calculated for each conditioning factor, representing the relationship between the classes of each factor and flood occurrence. Analyzing the Weight of Evidence (WoE) final results, it is evident that the slope with the built-up range of the landuse factor had the highest weight among all other factor classes. This indicates that areas with built-up landuse exhibit maximum susceptibility to flooding in the catchment.

On the other hand, the area of 490 km^2 classified as “high” susceptibility is predominantly visible upstream of Tafedna village along the Igouzoulen Oued. It also encompasses Oued Tidzi, Had Dra village, and the drains near El Hanchane - Lagdadra communes, along with the outlet of Ouazzi Oued. The remaining classes, namely “very low” to “low” susceptibility, cover the remaining area, particularly in higher altitudes and upstream regions of the watersheds.

About the validation, the AUC values obtained during the validation process for all models. It is worth noting that all landslide susceptibility models with AUC values exceeding 0.9 were considered outstanding, particularly the AHP model.

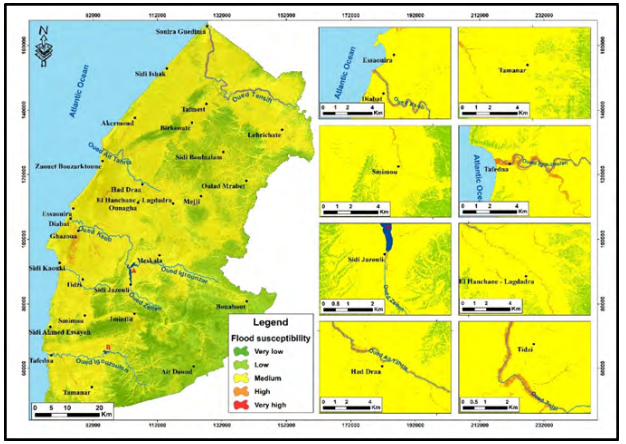

Figure 1. Flood susceptibility map derived from AHP analysis.

Conclusion

In conclusion, utilizing AHP, FR, and WoE models has enabled the classification of flood susceptibility levels in the Essaouira province without explicitly indicating water depth. The province has been categorized into five susceptibility classes. While the areas with high and very high susceptibility occupy smaller proportions, the moderate, low, and very low susceptibility classes cover larger percentages of the study area.

The severity of flood susceptibility is particularly significant in certain localities characterized by low-altitude plains and gentle slopes. These areas, including Essaouira, Smimou, Sidi Jazouli, Tafedna, and others, are exposed to high levels of risk, putting residential, agricultural, and infrastructure areas, such as roads and bridges, in danger of significant damage. The hazard exposure, along with the risk magnitude, ranges from high to very high susceptibility. The analysis of selected factors across all models consistently high-lighted the importance of slope, elevation, and stream order (flow accumulation) in determining flood susceptibility and contributing to flood occurrence.

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Avaliação do potencial de águas subterrâneas na área de Ait Abdellah com recurso à deteção remota e SIG

Assessment of groundwater potential in the Ait Abdellah area by using remote sensing and GIS

Asma Bougayou
Abdellah Khouz
Fatima El Bchari
Jorge Trindade
Mustapha Ikirri
Siham Afraou
Farid Faik
Blaid Bougadir

Resumo

Este estudo avalia o potencial de águas subterrâneas na região de Ait Abdellah (Anti-Atlas Ocidental, Marrocos) através da integração de técnicas de Sensoriamento Remoto e SIG com o método Analytic Hierarchy Process (AHP). Dez fatores, incluindo densidades de lineamentos e drenagem, declive e permeabilidade, foram ponderados para gerar um mapa de potencial aquífero validado pela curva ROC (AUC = 80%). Os resultados identificam zonas de alto potencial associadas a características estruturais e litológicas, oferecendo um instrumento de apoio à decisão para a gestão sustentável de recursos hídricos em regiões áridas.

Palavras-chave: potencial aquífero; sensoriamento remoto; SIG; AHP; Anti-Atlas.

Asma Bougayou
Laboratory of Applied Sciences for the Environment and Sustainable Development (SAEDD), Essaouira Higher School of Technology, Cadi Ayyad University, Marrakech, Morocco
Abdellah Khouz
Centro de Estudos Globais, Universidade Aberta, Lisbon, Portugal
Centre of Geographical Studies, Institute of Geography and Spatial Planning, Universidade de Lisboa, Lisbon, Portugal
Fatima El Bchari
Centro de Estudos Globais, Universidade Aberta, Lisbon, Portugal
Department of Earth Sciences, Polydisciplinary Faculty of Safi, Cadi Ayyad University, Marrakech, Morocco

Abstract

This study assesses groundwater potential in the Ait Abdellah region (Western Anti-Atlas, Morocco) using Remote Sensing and GIS integrated with the Analytic Hierarchy Process (AHP). Ten factors, including lineament and drainage densities, slope, and permeability, were weighted to produce a groundwater potential map validated by the ROC curve (AUC = 80%). Results identify zones of high potential correlated with structural and lithological features, providing a valuable decision-support tool for sustainable water resource management in arid regions. The methodology offers an efficient, replicable framework for hydrogeological assessment in similar hard rock terrains.

Keywords: groundwater potential; remote sensing; GIS; AHP; Anti-Atlas.

Jorge Trindade
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal,
Centre for Global Studies, Universidade Aberta, Lisbon, Portugal
Mustapha Ikirri
Geology Department, Faculty of Sciences, Université Ibn Zohr, Agadir, Morocco
Siham Afraou
Blaid Bougadir
Laboratory of Applied Sciences for the Environment and Sustainable Development (SAEDD), Essaouira Higher School of Technology, Cadi Ayyad University, Marrakech, Morocco
Farid Faik
Geology Department, Faculty of Sciences, Université Ibn Zohr, Agadir, Morocco

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0000-0002-9971-6249
0009-0007-0630-344X
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Introduction

In Morocco, water scarcity represents a major challenge, particularly in semi-arid regions like the Anti-Atlas, where the effects of climate change exacerbate the pressure on already limited water resources [1-3]. The Ait Abdellah region, located in the western Anti-Atlas, exemplifies these issues. Understanding a discontinuous aquifer within a fractured Precambrian basement covered by Paleozoic formations [4,5], along with complex tectonic constraints, is essential to analyze the distribution and dynamics of groundwater. In this context, the study aims to explore the use of remote sensing techniques (Sentinel-1 and Landsat 8 OLI images) combined with the Analytic Hierarchy Process (AHP) to map groundwater potential in this region [3, 6-11]. By using factors related to fracturing, such as lineament density and proximity, as well as hydrogeological and topographic variables, this study aims to enhance the understanding of local hydro-structural processes and map groundwater potential areas. The accuracy of the results was validated using the ROC curve [3, 7-11]. This multidisciplinary approach offers practical solutions for sustainable and effective water resource management, particularly by identifying zones suitable for future exploratory drilling.

Study Area

The study area, located in the southeast of the Kerdous massif in the western Anti-Atlas, covers 467 km² between latitudes 29°60'00"N and 29°40'00"N and longitudes 8°60'00"W and 8°40'30"W (Figure 1). Characterized by an arid climate, this region receives an average annual rainfall of 150 mm, with summer temperatures reaching approximately 30°C [8,12].

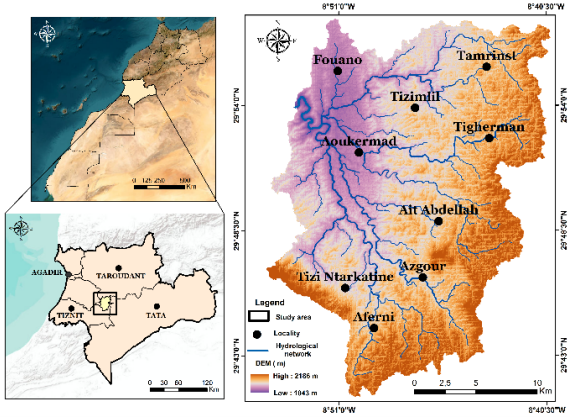

Figure 1. Geographical location of the study area.

The geology of the Ait Abdellah area is characterized by the presence of Upper Precambrian II conglomerates, discordant on the quartzites of Lower Precambrian II, as well as a basal series composed of siltstones intercalated with limestones, sandstones, and volcanic formations [13]. Specific formations, such as the silicified dolomites of Tamjout, with a thickness of 17 m, and the dolomitic sandstones, are also observed [13, 14]. Furthermore, the dominant layers belong to the Tata-Taroudant group. This series, with a thickness of 50 m, consists of an alternation of limestones, marls, and black dolomites [15-17]. Structurally, the Ait Abdellah area, located to the east of the Kerdous massif, exhibits a sub meridional Hercynian structure affecting the Precambrian basement and the Cambrian cover of the Issafen syncline to the east and the Fouano syncline to the west [5]. This region has recorded several major tectonic events, including the Eburnean, Pan-African, and Hercynian orogenies. The dominant structures are oriented N-S, particularly visible in the Ait Abdellah and Alma buttonholes, while the Fouano syncline shows NE-SW and NNW-SSE directions, with secondary orientations of E-W and NW-SE [4, 17]. From a hydrogeological point of view, the region has a discontinuous aquifer, resulting from the interaction

between geological formations and the presence of faults, which increases the capacity of these formations to store and transmit water.

Methodology

The methodology (Figure 2) for modeling GWP is based on data collection (Souss Massa Hydraulic Basin Agency, water service, satellite images), and remote sensing analysis (OLI and Sentinel-1 images). Ten conditioning factors are selected (Intersection of the hydrographic network and lineaments, drainage density, lineament density, node density, drainage distance, lineament distance, distance to nodes, permeability, slope) and an inventory of 117 boreholes, wells, and drills. The application of the AHP method is based on a pairwise comparison matrix (Table 1), and the validation of results through field data and the ROC curve [3, 8, 11].

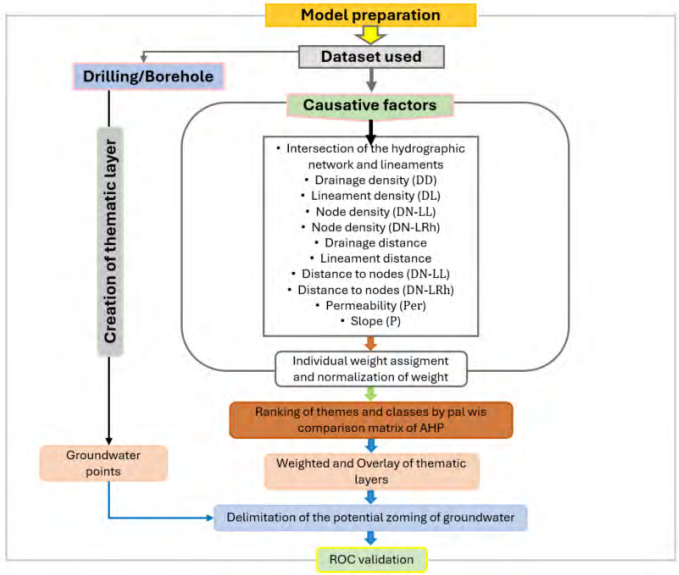

Figure 2. Schematic diagram of the methodology used.

The consistency of the matrix of selected factors for the groundwater study was verified using the consistency ratio (*CR*), as described in Equation 1 [18,19]. This ratio measures the degree of consistency by comparing the consistency index (*CI*) of the matrix with that of a random reference matrix, called the random index (*RI*).

$$CR = \frac{(CI)}{(RI)}$$

The consistency ratio (*CR*) evaluates consistency using the consistency index (*CI*), derived from Equation 2. The random index (*RI*) is calculated based on the average consistency index obtained from a sample of 500 randomly generated pairwise comparison matrices. The value of *RI* depends on the number of factors used.

$$CI = \frac{\lambda_{max} - n}{n-1}$$

The significant absolute eigenvalue of the pairwise comparison matrix, , is determined from Equation 3 [18]. The corresponding eigenvector, W, is associated with , while ($i = 1, 2, \ldots, n$) represents the weighted value of each factor, easily obtained from the matrix specified in equation (3) [19]. In this context, (n) denotes the number of factors conditioning groundwater [20, 21].

$$\lambda_{max} = \frac{1}{n}\sum^{n}_{w_i}\left(\frac{(AW)_i}{W_i}\right)$$

Fac										
Dr-D	1									
Dist=R	1/2	1								
D-L	1/3	1/2	1							
Dis-L	1/2	1/2	1/2	1						
L-N-den	1/3	1/2	1/2	1/2	1					
Dis-N	1/2	1/3	1/2	1/3	1/2	1				
D-N L/ Rn	1/3	1/2	1/3	1/2	1/3	1/2	1			
Dis-N Rn	1/2	1/4	1/2	1/3	1/2	1/3	1/3	1		
S	1/4	1/3	1/2	1/3	1/3	1/2	1/4	1/3	1	
Per	1/3	1/3	1/5	1/4	1/3	1/2	1/3	1/2	1/2	1

Table 1. Pairwise comparison matrix of the various factors influencing potential groundwater zones.

The consistency of all judgments is verified by ensuring that the AHP method suggests a consistency ratio (*CR*) of 0.1 or less. However, if the consistency ratio exceeds 0.1, it is necessary to revise, reevaluate, recalculate, and correct the judgments in the matrix by identifying the source of inconsistency and making adjustments until a *CR* of less than 0.1 is achieved [22]. In this study, the consistency index (*CI*) is calculated for an eigenvector of 10.87, with *n* equal to 10 and a *RI* of 1.49. The consistency ratio is calculated as *CR* = 0.065, which is below 0.1. Since the *CR* value is lower than the threshold (0.1), the consistency of the matrix is confirmed.

Once the thematic layers corresponding to the different evaluation factors have been developed, along with their normalized weights and respective individual classes, all these elements are then integrated into a GIS environment. This integration is carried out using the weighted overlay technique, which combines the different layers at the pixel level, according to Equation 4.

Where, **GWPA** = (Drainage density × 2,01) + (Lineament density × 1,31) + (Lineament node density × 0,98) + (Density of lineament hydrographic nodes × 0.96) + (Distance from rivers × 1.62) + (Distance from lineaments × 1.25) + (Distance from lineament nodes × 0,78) (Distance from lineament nodes to hydrographic network × 0.57) + (Slope (*S*) × 0,40) + (Relative permeability (*Per*) × 0,34) **(Equation 4)**.

The ROC curve was used to assess the capability of the AHP method in mapping potential groundwater [3, 8, 23].

Results

The groundwater potential map, generated by the AHP method (Figure 3), was classified into five categories, ranging from very low to very high potential (Table 2). It shows that the very high potential class represents 19.52% of the studied area, with a predominance of zones with moderate potential. The very high potential zones are mainly located to the north of Tizi Mlil, west of Awkermad, and downstream, characterized by a high density of faults and nodes, as well as the permeability of geological formations near drainage networks. Favourable geological formations include limestones, dolomitic limestones, volcanic formations, conglomerates, and alluvial plains. The main localities, such as the lower basin, Awkermad, and Tizi Mlil, are located in areas with high to very high potential, thus recommending site selection near these zones to avoid water shortages. In contrast, areas with low potential are situated in mountainous terrain or in lithological formations with low permeability, such as rhyolites and ignimbrites. Avoiding these areas would reduce the costs of exploration and exploitation of groundwater resources. These results are consistent with those of [10] in the Tata basin, [3] for the Ifni basin, and [9] in the Kerdous region, which show similar trends.

GWPA	
Very low	22.35
Low	20.46
Moderate	19.17
High	18. 50
Very high	19.52

Table 2. Percentage surface of the GWPA class corresponding to each model.

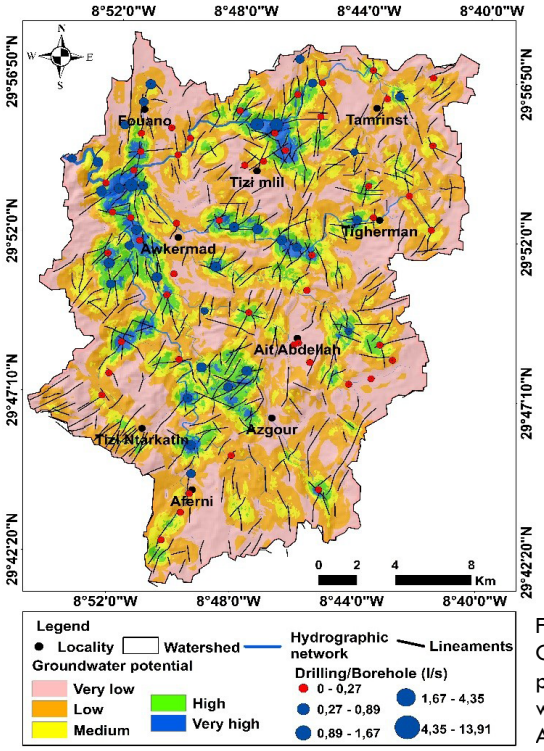

Figure 3. Groundwater potential in the watershed using the AHP method.

The validation of the potential results was carried out using the area under the ROC curve (AUC), as indicated by [3, 24, 25]. The ROC curve shows that the AHP method achieves a validation rate of 80%. These results are consistent with the studies of [7], [7] and [3]. Indeed, the ROC curve highlights the high predictive capability of the AHP method.

Conclusion

The mapping of groundwater potential areas in the Ait Abdellah was carried out by applying the Analytic Hierarchy Process (AHP) model, along with remote sensing techniques and Geographic Information System (GIS) technologies. Various geological, hydrogeological, and topographical factors were integrated to generate multiple thematic maps, which were then weighted and overlaid in a GIS environment. Weights were assigned based on the impact of each factor on water availability. The Groundwater Potential area (GWPA) map was developed from this combination of factors and classified into four classes: very high, high, moderate, and low. The validation of the results was performed by comparing the GWPA map with 117 existing wells, and the AUC was calculated at 80%, indicating the predictive accuracy of the AHP method. The results can serve as a valuable tool for water resource management by professionals in the field. To improve the accuracy of the AHP method, the use of high-resolution geospatial data is essential. This approach can be extended to similar mountainous areas.

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Águas subterrâneas na governação do nexo Água-Energia-Alimentação em áreas periurbanas exteriores

Groundwater in the Water-Energy-Food nexus governance in outer peri-urban settlements

João Carrilho
Abdellah Khouz
Jorge Trindade

Resumo

O nexo entre água, energia e alimentos (AEA) é um desafio para a sustentabilidade nas áreas periurbanas devido aos factores institucionais inerentes e práticas correspondentes. Sugere-se uma estrutura participativa multissectorial e multinível para impulsionar a mudança estrutural e formalização do regime sociotécnico, ligando reguladores, fornecedores e consumidores. Com base num estudo de caso em assentamentos periurbanos informais em Moçambique, identificam-se questões e potenciais pontos-de-entrada a considerar na promoção de inovações institucionais locais. A associação local de fornecedores privados de água é sugerida como ponto de entrada, por ser semiestruturada e equidistante entre utilizadores e criadores de ciência e tecnologia.

Palavras-chave: inovação institucional; regime sociotécnico; nexo AEA; água subterrânea; periurbano; Moçambique.

João Carrilho
Centro de Estudos Globais, Universidade Aberta, Lisbon, Portugal
Abdellah Khouz
Centro de Estudos Globais, Universidade Aberta, Lisbon, Portugal
Laboratory of Applied Sciences for the Environment and Sustainable Development (SAEDD), Higher School of Technology Essaouira, Cadi Ayyad University, Marrakech 40000 – Morocco
Jorge Trindade
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal,
Centre for Global Studies, Universidade Aberta, Lisbon, Portugal

0000-0002-6757-5429
0000-0003-4514-5281
0000-0001-5610-5942

Abstract

The water-energy-food (W.E.F.) nexus is a challenging sustainability issue in peri-urban areas due to their inherent institutional drivers and corresponding practices. A multilevel and multisector participatory framework is suggested to drive the structuration change and sociotechnical regime formalization linking regulators, suppliers, and consumers. Based on a case-study on informal peri-urban settlements in Mozambique, issues and potential entry-points are identified to consider when promoting local institutional innovations. The local private water suppliers' association is suggested as the entry-point, as they are semi-structured and equidistant between the users and the science and technology creators.

Keywords: institutional innovation; sociotechnical regime; groundwater; peri-urban; Mozambique.

Introduction

In twenty five years, it is expected that two-thirds of the world increasing population will be urbanized (Ritchie, Samborska, and Roser 2024). This shall happen through urban expansion or sprawl, leap-frogging and in-situ urbanization from short distance rural exodus (Liu et al. 2014; OECD and Sahel and West Africa Club 2020), Such process includes peri-urbanization. All dimensions of sustainability relate to the resource management in varying degrees, depending on the physical and socio-cultural characteristics of the peri-urban domain in addressing the transition and change.(Adell 1999; Dadashpoor and Ahani 2021; Iaquinta and Drescher 2000; Romero-Lankao, Bruns, and Wiegleb 2018; Sahana et al. 2023)social, economic, and environmental consequences in these areas. Such a process converts the peri-urban areas into a challenging part, the guidance of which requires a comprehensive understanding of them in all its dimensions. The most important of these dimensions are effective forces and mechanisms in the formation and expansion of peri-urban areas around metropolises. With this in mind, this paper, using a critical realism approach and a systematic review, explains first the effective objective forces in the formation and expansion of peri-urban areas in the form of different patterns of peri-urbanization. Then, the driving forces affecting these patterns are examined. Finally, the underlying causal structures and mechanisms affecting these forces are explained. The results indicate a three-level framework including (a.

This study follows previous research on land use planning priorities in outer peri-urban village-type informal settlements north of Maputo, Mozambique. The research identified the need for institutional innovation to address the provision of public goods such as water sources, sanitation, and energy. It also emphasized the importance of interconnectedness related to (food) market hubs, roads, and railways.

The water-energy-food (WEF) nexus revealed to be an issue deserving a fresh look.

The water-centricity in this study and the attraction to the groundwater management was in part motivated by considering it as a typical common-pool resource, which so much influenced the Östrom theorization of the governance of commons (Ostrom 1990), and her rules of boundaries, authority and power, information and aggregation, always to be considered in institutional innovations applied to any setting, in this case of peri-urban areas. Frequent interaction of actors in hybrid, temporary or circumstantial institutions and rules, both formal and informal, under a set of social preferences and values, affects power relations, improve cooperation, and make social participation relevant in avoiding a “tragedy of commons”.

The WEF nexus, as topic of (peri-)urban sustainability studies and as related to institutions with a role in land use planning, has been, over more than thirty years, the subject of differing conceptual and operational debate on their completeness and relevance. Geels (2004), Fuenfschilling and Tuffer (2014), and Narain et al. (2023) address the structuration of socio-technical regimes based on hydraulic, market, and knowledge logics, as well as the formal-informal dialogue and policy and political implications. While Smajgl et al. (2016) question the water-centricity of the nexus, Zhang et al. (2019) provide a more flexible choice based on a comprehensive review of a range of mostly context and scale responsive methods of modelling, assessment, and management of the sectors, their relevant combination in pairs, addressing integration and interdependence, collaboration and inter-connectedness, and suggests research in characterization, connection mechanisms, collaborative decision, and governance. Törnqvist (2007) systematizes approaches and frameworks of planning support and adoption of technological systems, based on broadly common sets of goals and objectives, indicators, degrees of participation, and external factors.

The research question

The study questions how to identify the entry point for innovations that local institutions could enact to improve the sustainability of common water resources under the WEF nexus approach in outer peri-urban village-type informal settlements. This question assumes that the institutions themselves have to identify their boundaries of action, the areas and levels of authority of actors, the rules for decision and their enforcement, and mechanisms to resolve conflicts and incoherences (Ostrom 1990).

Socio-geographic context

The reference settlements are located in inland sand dunes at altitudes between 20 and 70 m, and crossed by streams of a 2nd order watershed (Bobole River) of the Nkomati River basin (Cendón et al. 2020). There is no meteorological station in the study area and information is regional: the average annual precipitation is 768 mm, lower than evapotranspiration (annual average of 1,190 mm), only higher from December to March; the average temperature is 22.9 °C (Impacto 2012). A biodiversity reserve is present. The area is located along a major road linking the hinterland to the capital and is served by three mobile telecommunication operators. The settlements are of village type (Iaquinta and Drescher 2000), with an estimated total population of 20,000 inhabitants, organized into a cluster of neighborhoods, three levels below the district level, where some administrative sector representations exist, but are understaffed and under-resourced. Formal private operators provide most of the drinking water locally. The area is crossed by high and medium voltage power lines originating in distant hydropower plants serving the capital of the country, with a local substation and a still underdeveloped local distribution network. A small furrow irrigation system was built in the settlement and a variety of irrigation systems, from sprinkler to gravity, and water management practices are well established and used upstream the main basin.

Access to resources of land and water is generally viewed as easy and equitable, but tensions remain between formal and informal rules, the former used for securing tenure and conflict settlement with external actors, and the latter more frequently used for record and local conflict resolution. Social organization is based on occupation, religion, and place and idiom of origin. Young commuters bring urban values and behavior as well as information and participate in local meetings. Long term residents also commute daily to the cities and are thus exposed to urban values and information on innovations. These data justify the qualification of the settlements as transitional village-type, as argued above.

Figure 1 provides information on the occupation of settlements, groundwater bores, secondary and tertiary surface water streams, used for horticulture, and wastewater disposal. The inclusion of health centers is justified by the fact that these are the institutions in charge of ensuring water quality and promotion of sanitation standards. The inclusion of the dike is justified by the fact that farms along the Nkomati (Incomáti) River are exposed to elevated risk of floods and cyclones.

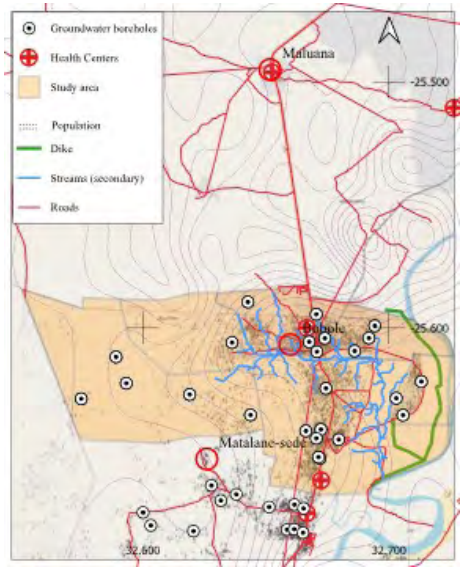

Figure 1. Groundwater sources location relative to residential areas.

Groundwater sources were located within densely populated quarters where septic tanks and pit latrines are common, and close to horticulture gardens, where wastewater collection or control of use of fertilizers are absent.

Local social institutions are hybrid of traditional and statutory, their leaderships are not elected and there is a relationship between traditional and appointed officials, including at kinship level. Local and external notable economic actors also sometimes exercise power. Apart from the agricultural private sector, a beverage industry is also located in the settlements cluster.

Conceptual framework for WEF responsive institutional innovations

A framework is suggested to assist in identifying at which institution and at what level it is more likely that innovations contribute more effectively to advance the sustainability of groundwater management, considering the context.

Based on the literature review, it is conceived that the nexus in peri-urban areas goes beyond water, energy, and food, connecting at least to climate and technology (e.g. Echeverry, Marques, and Pereira 2024), which are increasingly viewed and organized as sectors in their own right. It is also conceived that a component of one sector is more relevant in the intersectoral connections. For instance, in the climate sector, rainfall is more related to food production than other climate components.

The multi-sector coordination is of a horizontal nature, i.e., the actors are working at the same institutional level. These include formal and informal actors from the public, private, and social sectors.

Figure 2 represents intersectoral linkages and components within the sectors. The positions of water, energy, and food are interchangeable and depend on the context.

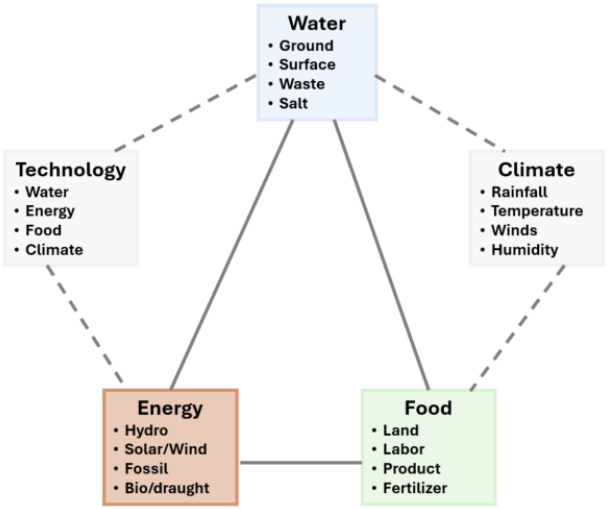

Figure 2. WEF governance: inter-sectoral framework

Similarly, some processes, like the management of groundwater, are more scientific-technically intensive with corresponding higher needs of vertical collaboration. For instance, there is a limited impact of local-traditional knowledge in hydrogeology research and deep groundwater abstraction technologies, compared with shallow wells and wastewater management practices. Within each sector, there are regimes, such as the scientific-technological regime, the policy-regulatory regime, the market operator regime, the consumption and user regime, and the socio-cultural regime (Geels 2004) which need coordination, including vertical, and combine into a wider socio-technical regime. The assessment of their level of structuration and the resolution of potential incoherences between them is context dependent (Fuenfschilling and Truffer 2014) . At the local level, it is suggested that their position in the formal-informal dialogue and their social recognition, legitimacy, and interaction are base criteria to determine the preferred entry point to mobilize responsive institutional innovations.

Methodology and Limitations

The case study from which this study derived used a mixed method qualitative approach, including expert opinion, focus groups, interviews, participatory GIS and basic spatial analysis. A supplementary literature review was undertaken to shed new light on the qualitative and geographic information collected for the above mentioned case study. Relevant national legislation was also studied and opportunistic interviews with experts on water supply, including private water suppliers. Information on the social composition and organization, the difficulty of accessing water, energy, and land, as well as on local social groups, was retrieved for analysis. The mean distance to nearest water point was calculated for the groundwater sources, for the study area and overlaid on the medium-sized rural clusters with densities between 750 and 1,500 inhabitants per km^2 (Commission et al. 2020). The mentioned institutions with a role in the water supply by-laws were located.

The analysis followed the suggested framework and developed a vertical collaboration map to identify the entry point for institutional development.

This study faced limitations such as lack of information on local hydrogeology, meteorology, and hydrometry due to lack of local geological studies and meteorology stations in the study area. Regional data were used to mitigate this limitation. Local point-by-point study was not possible because of unsafe conditions of access because of social unrest. Open ended interviews were conducted with key informants, two farmers, and water consumers, both in the risky low areas, the sandy medium altitude of the study area.

Results and Discussion

Case study information retrieval

The main sources of drinking water are 24 standalone microsystems based each serving up to 500 client households. The systems rely on groundwater abstraction from bores equipped with solar powered pumps or connected to the local power grid, under nationwide quantity and quality regulations (GoM 2015). The groundwater bores have a depth of up to 90 m and reach where the water is semi-confined between aquitard layers. This semi-confined water may be polluted by sanitation practices, as 70% use septic tanks and pit latrines and 20% dispose of their waste directly on surface streams. Although none of the bores in the region registered levels of nitrites and nitrate above the international guidelines, the location of the bores within the most densely populated areas of the settlement raises the need for regular monitoring of water quality. The regulated control period is five years, to renew the abstraction and supply license. Given the climatological context and the significant annual precipitation received, along with the substantial recharge of at least 1 million m^3 per year, it can be concluded that there are likely more concerns related to water quality (pollution) than to water quantity (availability). The level of precipitation supports a stable water supply, yet anthropic activities could pose risks to the overall water quality.

More than 50% of the population derives their livelihood from agriculture, in both subsistence farming and as wage-laborers in medium to large food crops farms. Some farms in the lowlands along the Nkomati River are periodically affected by floods and salinization following drought events. The sluice gates of the rivers and dikes are not functional and do not contribute to controlling the water flow. Less than five percent spend more than half an hour accessing some source of power, including wood fuel or charcoal. No schools other than primary schools are present in the area. Long-term residents are 41% of the total population.

But more than thirty percent are newcomers with less than five years of residence, two thirds of which are young. The origin of the population is either local or coming from a nearby rural district, pointing to a more rural traditional overall values and behaviors. However, 21% come from a neighboring urban area.

Table 1. presents the mean distance between the bores for the whole study area and for the more densely populated neighborhoods.

Boroughs	Bore Points	Mean distance (m) to nearest	Max. pop. density in EA ppl/km²
All 5 boroughs	24	1055	1684
Bobole	8	973	1420
Matalane-sede	7	613	1684
Note: EA = enumeration Area			

Table 1. Mean distance to the nearest point, in meters, and maximum associated population density.

Research institutions, universities, colleges, and high schools are absent in the area, but within commuting distance in neighboring urban centers. At primary schools, a basic emergency plan was disseminated and originated from the establishment of committees for disaster risk management. Sector specialist staff are present at province and district level and may have a trained focal point at lower level. These do not exist in the study area. There are two health centers in the area. These centers have the mandate to monitor and certify the quality of drinking water. Figure 3 presents the levels of coordination within each sector under the regimes, logics, and structuration frameworks (Geels 2004; Fuenfschilling and Truffer 2014).

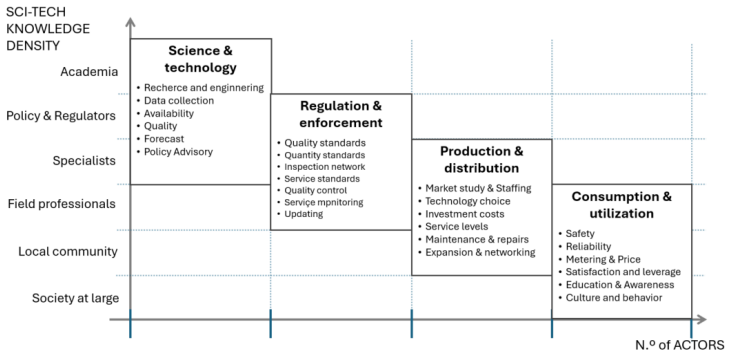

Figure 3. Socio-technical regimes and levels of coordination within each sector

With reference to production and distribution (Figure 3), the private operators are organized into an association, which have statutory mandate under the national legislation and where some incoherence may occur because of market interests, but they have regular interaction and boundary rules. The licenses have a period of five years. The operators interact monthly with the consumers for tax collection purposes and eventually for evaluation of satisfaction.

Consumers are informally grouped by occupation, focusing mainly on the quantity and price of drinking water. They also cooperate during floods and droughts, exchange seeds and seedlings, and share knowledge about farm management.

The land use planning priority actions obtained from the case study attribute high priority to register and regularize rights, waste management, dikes maintenance and to collaboration between informal and formal authorities. Definition of baseline standards for service levels to access public goods and services. There were not, however, specific references to groundwater quality and protection.

These results indicate that the actors occupying the best position in terms of equidistance between formal and informal institutions and their social recognition, legitimacy, and interaction by both the upper and lower levels are the associations of private water suppliers. From this, specific working groups may emerge to coordinate the water-land pair of the nexus, and the water-energy pair, gradually involving local primary schools and specialists.

Setting rules of entry and exit, managing power relations, and a set of incentives and penalties within the national legislation are of key importance to enable an environment for institutional innovations and progressive structuration.

Conclusion

The fieldwork for the case study has shown that sustainability is related to social cohesion, with its dimensions of inclusion, participation, and trust in institutions, which is, in turn, related to the formal-informal power relation dialogue, the effectiveness and competence of addressing equality in access, and management of resources. The legitimacy of institutions in hybrid contexts is challenging and depends on the local institutional culture. Sustainable management of groundwater within the Water-Energy-Food nexus requires institutional innovations that improve social cohesion, enabling global changes to be addressed locally. Institutions should be structured to facilitate horizontal and vertical cooperation, making the resource of groundwater accessible to common knowledge, action, and awareness. In the same way that a researcher brings to the table information and forecast on availability and quality of groundwater and its relationship to surface water and climate, or to land for food production, the knowledgeable consumer may provide hints to assess quality, help in data collection, and make adequate use and disposal of a scarce common resource. The operators consistently engage with researchers and regulators, as well as consumers. Therefore, the operators' association serves as an appropriate entry point to establish a sustainable collaboration that leverages universal knowledge alongside local culture and values.

After identifying this entry point, working groups can be set up to use existing groundwater management data and enhance participatory land and energy management practices.

Future measurements in densely populated areas like Bobole and Matalane-sede are crucial to monitor water availability and quality. Selecting boreholes, technical solutions for water cycle and hydrogeologic measurements, and the development data protocols should involve all relevant stakeholders of the socio-technical regime.

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Avaliação das áreas suscetíveis a cheias na sub-bacia do rio Revúboè, Moçambique

Assessing Flood Susceptibility Areas in the Revúboè river sub-basin, Mozambique

Gustavo Dgedge
Celso Chivale
Jaime Magaia
Jorge Trindade

Resumo

Este estudo avalia a suscetibilidade a inundações na sub-bacia do rio Revúboè, em Moçambique, utilizando o método Analytic Hierarchy Process (AHP) e Sistemas de Informação Geográfica (SIG). Foram integradas cinco variáveis condicionantes – declive, hipsometria, uso do solo, solos e precipitação – para produzir um mapa de suscetibilidade a cheias. Os resultados indicam que 55% da área apresenta suscetibilidade alta a muito alta, concentrada nas zonas baixas próximas de Tete e Moatize. A análise apoia o ordenamento do território e a redução do risco de desastres naturais.

Palavras-chave: Suscetibilidade a cheias; AHP; SIG; Rio Revúboè; Moçambique.

Abstract

This study assesses flood susceptibility in the Revúboè River sub-basin, Mozambique, using the Analytical Hierarchy Process (AHP) and Geographic Information Systems (GIS). Five conditioning variables – slope, hypsometry, land use, soils, and rainfall – were integrated to produce a flood susceptibility map. Results indicate that 55% of the basin has high to very high susceptibility, concentrated in low-lying areas near Tete and Moatize. The analysis supports land-use planning and disaster risk reduction, providing valuable insights for managing flood-prone areas in the Zambezi basin.

Keywords: Flood susceptibility; AHP; GIS; Revúboè River; Mozambique.

Gustavo Dgedge
Celso Chivale
cchivale@gmail.com
Jaime Magaia
Faculty of Earth and Environmental Sciences, Pedagogical University of Maputo, Mozambique
Jorge Trindade
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Centre for Global Studies, Universidade Aberta, Lisbon, Portugal

0000-0002-5054-8440
0009-0006-0962-3097
0000-0001-5610-5942

Introduction

The Revúboè River sub-basin in Mozambique has a history of flooding, highlighting the importance of mapping hazard areas, which this study aims to identify. Flood maps are an important tool in preventing, controlling, and managing floods, as they allow for the definition of risk areas. They are also important in land use planning, particularly from the perspective of subsidising the prevention of natural disasters in the face of climate change, as well as helping to manage occupied areas. This research aims to identify the risk areas prone to flooding in the Revúboè sub-basin. These areas will be mapped using the AHP multicriteria analysis method and integrated into Geographic Information Systems.

Study Area Location

The study area comprises the Zambezi River basin, specifically the Revúboè River sub-basin. The Revúboè River sub-basin is in Mozambique, in the province of Tete. It flows into the Zambezi River immediately downstream of Tete City. The northern and eastern boundaries of the Revúboè sub-basin delimit the border between Mozambique and Malawi. To the west, it meets the Mavudzi River sub-basin, while to the south, the Revúboè River flows into the Zambezi River (Serafim, 2005). The study area covers six Tete province districts: Angónia, Chiuta, Cidade de Tete, Macanga, Moatize and Tsangano.

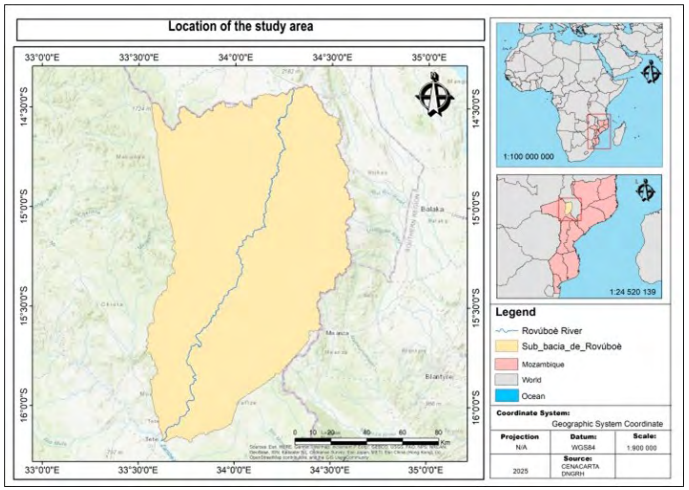


Figure 1. Location of the study area.
Source: CENACARTA edited by the Authors

Methodology

The methodology adopted used data geoprocessing to identify flood susceptibility areas in the Revúboè river sub-basin, backed by an extensive review of the specialised literature on areas of flood susceptibility. The thematic variables considered important to assess susceptibility are (slope, hypsometry, land use land cover, soils, rainfall). To assess exposure the variables considered important are road network, health care facilities, education facilities and population) were cross-referenced in a GIS (Geographic Information System) environment. flood susceptibility was assessed using the Analytical Hierarchy Process (AHP) method (Saaty, 2008).

i) Data sources and materials

Digital Elevation Model (MDE): was obtained from ALOS PALSAR, with a resolution of 12.5 meters. From this data, the sub-basin of the study area was delimited through automatic watershed delimitation using Hydrology ArcToolbox from ArcGIS 10.4.1.

This extension makes it possible to determine flow direction, calculate flow accumulation, delineate river basins and create drainage networks. The altitude and slope maps were also derived from this MDE, which were used to identify the lowest areas representing the greatest susceptibility of flooding in the study area due to the low altitude and the consequence of gravity draining the water to low areas and flatter slopes.

Soil distribution: the IIAM (Instituto de Investigação Agrária de Moçambique) geodatabase, originally at a scale of 1:1,000,000, was used to identify the distribution of soil types. Soil classes affect infiltration capacity and surface runoff and are essential to assess flood susceptibility.

Land use / Land cover (LULC): was obtained from the global land use raster database, originally from 2021 and at a resolution of 10m, provided by the European Space Agency, with 10 LULC classes, including vegetation type, exposed soil, crops and urban areas.

Rainfall distribution: was acquired from CRU (Climate Research Unit) Data, available at https://www.crudata.uea.ac.uk/cru/data/hgr/, originally with a spatial resolution of 0.5°. The geodata version used (CRU TS v. 4.06) was released on 26 May 2022, and this research included a 30-year time series (1991 – 2021) to create a matrix map of average annual rainfall. Data from the 2017 population census by INE (National Institute of Statistics) were used with geodata represented by village points with total population. Hospitals: A point location geodatabase from MISAU (Health Ministry) was used to locate health facilities.

ii) flood susceptibility assessment

flood susceptibility assessment in the Revúboè River sub-basin is based on the Analytical Hierarchy Process (AHP). AHP mathematically analyses paired comparisons between factors and experts' judgements and weights to evaluate qualitative or intangible criteria. Thus, factors or attributes are identified, which, when selected, are organised hierarchically, descending generally to the objective or solution to the problem(s) and down to the criterion, sub-criterion, and alternatives at various levels (Saaty apud Pimenta et al., 2019: 409). To determine the degree of importance and the weights of each criterion analysed, the methodology proposed by Saaty (2008) was used to structure the decision hierarchy, construct the paired comparison matrix, prioritise the alternatives and define susceptibility classes, which resulted in the definition of the susceptibility classes.

Reclassification and mapping of variables

Thematic maps of the independent variables are based on the methodologies described below. Weights were assigned to each class of the selected variables on a scale of 1 to 5, where 5 is the value with the greatest influence on flooding, and one is the lowest.

Hypsometry: The hypsometric map represents the variation in the altimetry of the morphology in the basin with the mean sea level as a reference. The map was obtained by classifying the MDE and then reclassifying it, where the altimetry classes were separated into an interval of 387.4 meters, giving a total of 5 classes. The weights assigned to the altitude classes were applied, as shown in Table 1.

Hypsometry class (m)	Slope (%)	Assigned Weight	Susceptibility Level
109 - 496	0 – 7	5	Very high
	7 – 20	4	High
496 - 884	20 – 39	3	Moderate
884 - 1.271	39 – 72	2	Low
1.271 - 2.046	>75	1	Very low

Table 1. Hypsometry and slope reclassification. Slope classes adapted from Leal et al. (2020).

Slope: The slope map represents the inclination of the land surface about the horizontal and is expressed as a percentage. The map was obtained by extracting the slopes from the raster generated from the MDE using the slope function in ArcMap, making it possible to discriminate the slope classes according to the IIAM classification (Table 1).

LULC: The land use and occupation map represents the different forms of land use and occupation in the study area. The ESA's global land use and occupation database was used for its preparation, and the images have a spatial resolution of 10 meters. The LULC information for the study area was extracted and classified in ArcGIS based on the legend provided on the ESA website. Table 2 shows the class's reclassification.

LULC class	Assigned Weight	Susceptibility Level
Permanent water bodies	5	Very high
Exposed soil	5	Very high
Built-up area	5	Very high
Shrub vegetation	3	Moderate
Cultivated land	2	Low
Pasture	1	Very low
Forest/tree cover	1	Very low

Table 2. Hypsometry and slope reclassification (Magaia, 2022).

Soils: the soil map classification is based on the pedological map of Mozambique, supplied by IIAM on a scale of 1:1,000,000, for which the study area was clipped. The weights for each soil class were applied according to Table 3.

LULC class	Assigned Weight	Susceptibility Level
Oxic red clay soils	5	Very high
Red clay soils	5	Very high
Shallow soils on non-calcareous rock	5	Very high
Black basaltic soils	5	Very high
Shallow soils on limestone	3	Moderate
Brown soils with a sandy texture	3	Moderate
Medium-textured red soils	3	Moderate
Lithic basaltic soils	3	Moderate
Lithic soils	2	Low
Greyish-brown sandy soils	1	Very low

Table 3. Reclassification of the soil map.

Rainfall: the average annual rainfall map was obtained using rainfall data (30-year series) from 1991 to 2021, obtained from CRU DATA - a high-resolution gridded time series climate data platform (Table 4).

The classification of annual precipitation in Mozambique can be adapted to reflect the specific climatic conditions of the country. According to the Mozambique Precipitation Atlas published by the National Institute of Meteorology (INAM), average annual precipitation varies significantly between regions, with values that can be less than 400 mm in some areas and more than 2000 mm in others.

Average annual rainfall class (mm)	Assigned Weight	Susceptibility Level
734 - 780	2	Low
780 - 828	3	Moderate
828 - 872	3	Moderate
872 - 908	3	Moderate
908 - 945	3	Moderate

Table 4. Reclassification of the average annual rainfall map.

Application of the multicriteria decision method

The flood susceptibility map will be the product of the spatial analysis of five variables, namely, slope, hypsometry, land use land cover, soils, rainfall. Variables represented in the thematic maps drawn up. It will involve two distinct phases of work: the theoretical phase, in which the weights will be assigned to the variables, and the operational phase, in which map algebra will be used to aggregate the thematic maps.

Theoretical phase: Weights were assigned to the variables using the AHP method and after expert consultation. A two-by-two comparison was made using a proposed scale where 1 is the minimum, and 9 is the maximum importance of one variable over another to define the relative importance of the criteria in terms of flood susceptibility. This is the most important part, as the values assigned to each variable directly affected the result obtained. Table 9 shows how weights were assigned as each element of the matrix indicates how important the variable in the left-hand column is to each corresponding variable in the top row. Therefore, when a variable is compared to itself, the only possible result is 1, which is equally important. As soon as all the variables intersect once, the matrix becomes simply the opposite of the initial procedure.

Vars	Slope	Hypso.	LULC	Soils	Prec.
Slope	1	3	4	5	7
Hypso.	1/3	1	3	4	5
LULC	1/4	1/3	1	3	4
Soils	1/5	1/4	1/3	1	3
Prec.	1/7	1/5	1/4	1/3	1
Total	1,93	4,78	8,58	13,33	20,00

Table 9: Example of variables in the pairwise comparison matrix.

With the relative importance values of the variables, it was possible to determine the statistical weights for each variable. The values were obtained manually by dividing each element by the sum of the elements in the column to which it belongs and averaging the columns to determine each weight, as shown in Tables 10 and 11.

Vars						Av	Weight (%)
Slope	0,52	0,63	0,47	0,38	0,35	0,47	47
Hypso.	0,17	0,21	0,35	0,30	0,25	0,26	26
LULC	0,13	0,07	0,12	0,23	0,20	0,15	15
Soils	0,10	0,05	0,04	0,08	0,15	0,08	8
Prec.	0,07	0,04	0,03	0,03	0,05	0,04	4
Total	1,00	1,00	1,00	1,00	1,00	1,00	100

Table 10. Determination of statistical weights for each susceptibility variable.

Variable	Weight (%)
Slope	47
Hypsometry	26
LULC	15
Soils	8
Precipitation	4

Table 11: Statistical weights of the risk variables.

To assess whether the weights calculated were true, it was necessary to calculate the consistency ratio (*RC* – Equation 1, which, according to Costa (2002), must be less than 0.10. The consistency ratio obtained was 0.06, attesting to the coherence of the hierarchy of the data classification.

$$IC = \frac{(\lambda máx - n)}{(n-1)} = \frac{(5{,}2865 - 5)}{(5-1)} = 0{,}0716$$

$$RC = \frac{IC}{IR} = \frac{0.0716}{1.12} = 0{,}064$$

Operational phase: One way to perform a multicriteria analysis is through map algebra: 1st by adding the weighted variables by criterion (Table 11) and 2nd For this stage, arithmetic operations were performed using the raster calculator tool of the ArcGIS software, where the reclassified flood susceptibility variables were associated. As a subsidy for this stage, the model presented by Equation was used.

$$S = (\omega D \times D + \omega H \times H + \omega LULC \times LULC + \omega Soil \times Soil + \omega R \times R)$$

ω - Weight of the respective parameter (obtained by AHP)

After obtaining the flood susceptibility map, flood susceptibility was reclassified into five hierarchical categories: very low, low, moderate, high and very high.

Results and Discussion

The multicriteria analysis method was used to calculate the maps of the conditioning variables, resulting in a flood susceptibility map (Figure 2).

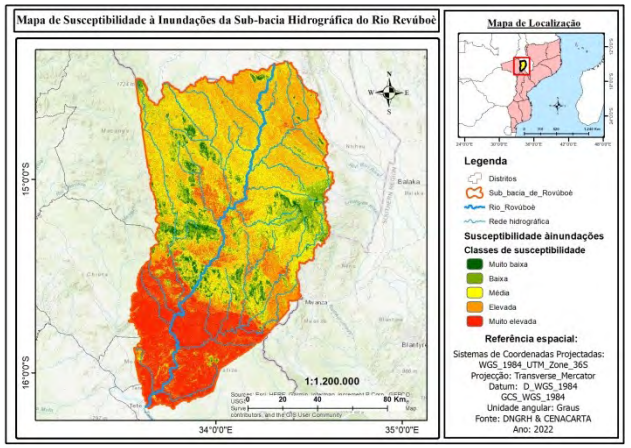


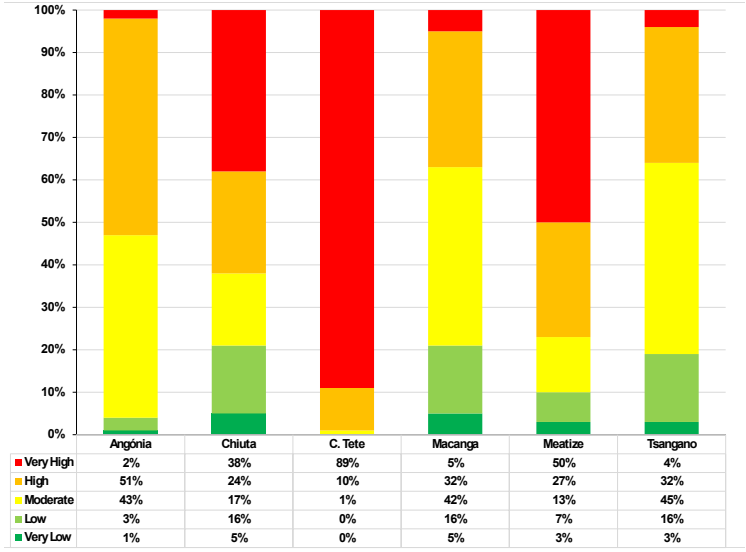
Figure 2. Flood susceptibility map of the Revúboè River sub-basin. Susceptibility classes shown from very low to very high

The map of areas susceptible to flooding was divided into five classes. Figure 2 shows the flood susceptibility map of the Revúboè River sub-basin. It can be seen that the areas considered to be of very high susceptibility are concentrated mainly in the lower regions of the sub-basin, evidently the location of the river mouth. The values are explained precisely by the fact that these levels of information present the greatest importance according to the paired comparison matrix, while the areas of low susceptibility are located in the middle course of the sub-basin, as they are areas with a mountainous slope. Analyzing the sub-basin area as a whole, the following indicators were obtained: Very low (3%), low (10%), Medium (32%), High (34%) and Very high (21%). It can be observed that the high susceptibility classes, followed by medium susceptibility, were predominant, representing, respectively, 34% and 31% of the total mapped area, showing that in general the sub-basin would have a high tendency to be flooded. The area with very high susceptibility was moderately significant, covering only 3,353.48 km², equivalent to 21% of the total area. The areas and percentages corresponding to the levels of flood susceptibility are summarised in Table 12.

Analysing the susceptibility map (Figures 2 and 3), Regarding the degree of susceptibility to flooding by districts of the Revúboè river sub-basin, the city of Tete in the 40.67 km²of the area covered by the sub-basin, 30.08 km², equivalent to 89% corresponds to the very high susceptib ility class, Moatize is mostly covered by very high susceptibility with 50%, corresponding to 2143 km² of the district's area. The district of Chiuta has a very high susceptibility level of 38%, equivalent to 894.55 km² of its total area.

Susceptibility Class	Area (km²)	%
Very low	462,3	3
Low	1726	11
Moderate	5074,25	31
High	5396,91	34
Very high	3353,48	21

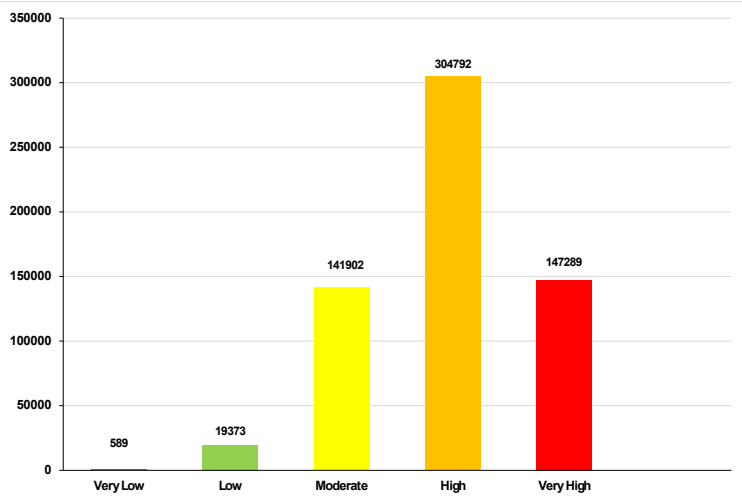
Table 12. Area covered by flood susceptibility classes.



Graph 1. percentages of area by degree of susceptibility in districts of the revúboè river sub-basin.

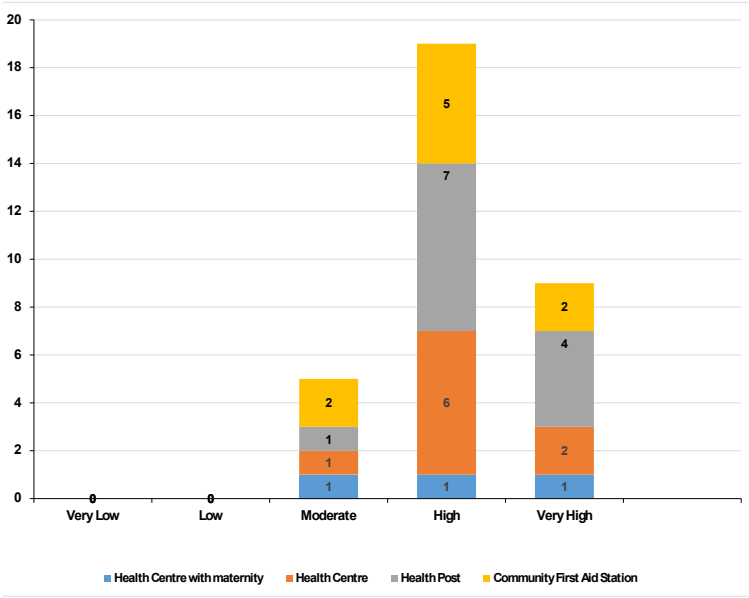
Exposed elements

Taking into account the number of inhabitants in susceptible areas, high susceptibility areas have the largest population with 304,792 inhabitants, followed by very high and medium susceptibility areas with 147,289 and 141,902 inhabitants, respectively. While 19,373 reside in low susceptibility areas, while very low susceptibility areas have 589 inhabitants.



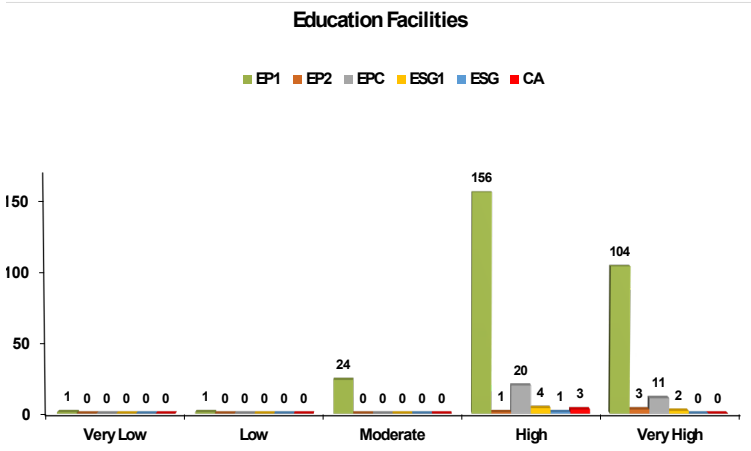
Graph 2. population distribution in relation to susceptibility levels

The very low and low susceptibility areas are not provided by any health services that may be affected by flooding. The medium susceptibility areas have 5 (five) health services that may be affected by flooding, namely one Health Centre with maternity ward, one Health Centre, one Health Post and two Community Aid Posts. The high susceptibility areas are well covered by health services, namely, 1 (one) Health Centre with maternity ward, 6 (six) Health Centres, 7 (seven) Health Posts and 5 (five) Community Aid Posts. In the very high susceptibility areas, 9 (nine) health services are affected by flooding, as illustrated in Graph 3.



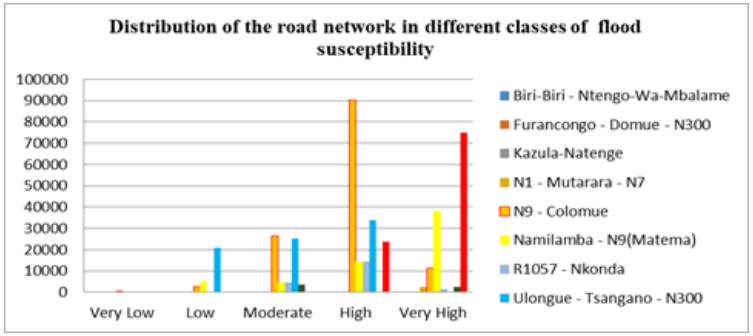
Graph 3. Distribution of Health Services in Susceptible Areas

Graph 4 shows the distribution of schools according to the level of education, with the majority of establishments being primary education institutions, the majority of which are in areas of high and very high susceptibility, with around 156 and 104 schools, respectively. 24 are located in areas of medium susceptibility, and only 1 school is located in areas of very low susceptibility, as well as in areas of low susceptibility.



Graph 4. Distribution of education facilities in susceptible areas

The Revúboè river sub-basin has a road network consisting of approximately 859.7 km of roads classified as primary, with the largest extension being in areas of high and very high susceptibility. The road that connects the districts of Tsangano and Angónia, in this case, the N9 – Colomue section, has 90.08 km in areas of high susceptibility and 11.42 km in areas of very high susceptibility, being the road with the largest coverage of susceptible areas. Another road that is heavily covered by areas of high and very high susceptibility is the Zobue – Tete – N6 section, which connects the city of Tete and the district of Moatize, 74.82 km of its extension are in areas of very high susceptibility and 23.87 km are in areas of high susceptibility.



Graph 5. Distribution of the road network in relation to susceptible areas

Conclusion

From this study it was possible to identify the areas susceptible to flooding in the Revúboè River sub-basin, Tete province. For this, the analytical hierarchical process (AHP) method and remote sensing technique were applied. To identify the susceptible areas, five variables were integrated: slope, hypsometry, land use and occupation, soil distribution and rainfall. The variables that most influenced the susceptibility analysis were slope and hypsometry, followed by land use, soil distribution and rainfall. The regions of very low susceptibility represent about 3% (462.3 km²) of the sub-basin area and are characterized by high altitudes and steep, mountainous slopes. However, the areas of very high susceptibility are concentrated near the mouth of the Revúboè River in low altitude areas ranging from 109 to 496.4 meters, and with flat and gently undulating slopes ranging from 0 to 7%, covering 3353.48 km² (21%) of the total area of the sub-basin. However, the areas at very high risk are low-lying areas and flat and gently undulating slopes, close to the mouth of the sub-basin. The areas most susceptible to flooding coincide with those flooded after the outbreak of Cyclone Idai in 2019 and Tropical Storm ANA in the first quarter of 2022, namely the City of Tete and the District of Moatize.

To analyze the exposure, the conditioning variables were the road network, the distance to health and education units and the population in relation to the susceptible areas. The flood susceptibility map studied from the algebraic integration of the reclassified maps of the conditioning variations, using the research (slope x hypsometry x land use and cover, soil x rainfall) According to the results, the very low and low risk areas represent 462.3 km² (3%) and 1726 km² (11%) of the total area of the sub-basin. The medium risk strongly covers the central to northern region of the sub-basin, covering about 5,074.25 km², equivalent to 31% of its area. The Tsangano district has the largest coverage of medium risk, covering 45% of its area, followed by the districts of Angónia and Macanga with 43% and 42%, respectively.

High and very high risk areas are located in areas with larger populations. Taking into account the number of inhabitants in susceptible areas, high susceptibility areas have the largest population with 304,792 inhabitants, followed by very high and medium susceptibility areas with 147,289 and 141,902 inhabitants, respectively.

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Abordagem multiescalar baseada em dados de satélite para a análise de tendências da linha de costa em Portugal Continental

Satellite-driven multi-scale approach for shoreline trend analysis in Mainland Portugal

Andreia Alves da Silva
Luís Pedro Almeida
António H.F. Klein

Resumo

Portugal continental possui cerca de 415 km de costa baixa-arenosa, dos quais 45% apresentam tendência de erosão. Com o objetivo de quantificar as tendências de variação da linha de costa portuguesa, foi usada a ferramenta CASSIE (Coastal Analyst System from Space Imagery Engine) e imagens Sentinel-2 (2015-2023) para gerar as linhas de costa, que foram analisadas em três escalas administrativas: nacional, regional e municipal. Os resultados indicam que 41% dos setores são estáveis, 31% em acreção, 19% em erosão e 9% em erosão crítica. O município de Ovar é o que apresenta a maior taxa média de erosão (-2,6 m/ano), abrangendo algumas das praias que apresentam os índices mais críticos de erosão costeira.

Palavras-chave: Linha de Costa, Monitorização Costeira, Erosão Costeira.

Andreia Alves da Silva
Luís Pedro Almeida
CoLAB +ATLANTIC, IPL-ESTM, Peniche, Portugal
António H.F. Klein
Coordenadoria Especial de Oceanografia, Universidade Federal de Santa Catarina, Florianópolis, Brazil

0000-0002-2767-6671
0000-0001-7805-9086
0000-0002-2565-8891

Abstract

Mainland Portugal has approximately 415 km of low-lying sandy coastline, 45% of which show an erosion trend. In order to quantify the shoreline trends, the CASSIE (Coastal Analyst System from Space Imagery Engine) tool and Sentinel-2 images (2015-2023) were used to generate the shoreline position, which were analyzed at three administrative scales: national, regional, and municipal. Results indicate that 41% of sectors are stable, 31% accreting, 19% eroding, and 9% critically eroding. Ovar municipality shows the highest average erosion rate (-2.6 m/yr), encompassing some of the beaches experiencing the most critical coastal erosion rates.

Keywords: Shoreline Position, Coastal Monitoring, Coastal Erosion.

Introduction

Portugal is a coastal country with a mainland territory composed of ~415 km of low-lying sandy coastlines. According to the Portuguese Environmental Agency, 45% of these low-lying areas registered a long-term erosion trend (Agência Portuguesa do Ambiente, 2024). These regression rates can be attributed to various factors, such as changes in sediment transportation, as result of an hhard engineering of coastal structures, and the construction of river dams during the 1950's. Identifying and mapping coastline variations is not only crucial for an effective coastal management, but to also pinpointing erosion hotspots along the sandy coasts.

Remote sensing tools such as CASSIE (Coastal Analyst System from Space Imagery Engine), represent a promising solution to address this challenge. This open-source free web-tool utilizes co-registered historical satellite imagery to automatically extract the waterline and perform several statistical analysis (Almeida et al., 2021).

In this work, CASSIE web tool was implemented to quantify the trends of the shoreline position of mainland Portugal beaches. With this information, it was possible to identify the coastal sectors that experienced erosion, stability, or accretion, and conduct a multi-scale approach that includes three different administrative levels: i) National; ii) Regional, and iii) Municipal.

Methodology

CASSIE web tool was applied to generate the statistics for mainland Portugal. The purpose was to analyse the short-term evolution of the coastline, therefore, the satellite mission used was Sentinel-2 (from 2015 to 2023). The shoreline used to generate the transects was defined based on the waterline. The transects were generated, with a spacing of 100 m, transversal to the waterline. The administrative chart of Portugal was also used and intersected with the transects, to provide a multi-scale approach.

A post-processing was later applied to delete the non-high tide data, and to reduce the possibility of errors related to a terrace. The linear regression rate (LRR) was acessed for all the sandy points.

Results

The results shown in Figure 1, reveal that 41% of the analysed transects show shoreline stability (LRR > -0.5 & <0.5 m/yr), 31% show accretion, 19% are experiencing erosion, and 9% critical erosion (LRR<-2 m/yr). The thresholds were adapted from Luijendijk *et al.,* (2018).

Figure 1. Shoreline trends for mainland Portugal (2015-2023).

Using a more detailed scale analysis, municipalities aligning with national trends and most affected by coastal erosion were identified, based on municipal averages of LRR. From all the analysed municipalities, Ovar is the one with the highest average erosion rate (-2.35 m/yr).

At the beach level, the highest mean erosion rates registered were: Praia das Furnas, Odemira (-8.4 m/yr), Praia de São Pedro de Maceda, Ovar (-6.1 m/yr), Praia das Dunas de Ovar, Ovar (-5.4 m/yr), Praia da Cova Gala (south), Figueira da Foz (-4.1 m/yr), Praia da Cova Gala (north), Figueira da Foz (-3.6 m/yr), Praia do Furadouro north, Ovar (-2.9 m/yr), Praia da Costa de Lavos, Figueira da Foz (-2.8 m/yr), Praia da Falca, Alcobaça (-2.7 m/yr), and Praia do Furadouro south, Ovar (-2.6 m/yr).

Figure 2. Shoreline trends for a sector of Figueira da Foz municipality.

Discussion

The comprehensive data approach reveals that the municipalities with the highest erosion rates may not necessarily correspond to those with the more beaches with critical erosion rates. One example is the Figueira da Foz Municipality, that has a mean LRR of 0.5 m/year and is classified as a stable, eventhought there are 3 beaches classified as “top beach erosion” located in this municipality. This is the result of the impact of the northern jetty extension of Figueira da Foz Port (in 2009). It generated accretion in the north beaches of the port and critical erosion in the south. The CASSIE results were able to detect these rates (Figure 2).

Conclusion

Analysing the results by municipality, we emphasize the importance of always considering the geomorphological context of the area, as the results may: 1) Experience critical rates in beaches strongly influenced by fluvial dynamics of sediment transport, as seen with Praia das Furnas,at the mouth of the Mira River; 2) Present stable municipalities with beaches undergoing critical erosion: the case of Figueira da Foz, where two beaches are experiencing critical erosion, which, in spite of significant areas of coastal erosion within the municipality, there are other sectors characterized by stability and accretion, resulting in a stable average rate of 0.5 m/year, underscoring the importance of examining with a more detailed scale of analysis; 3) Be similar to the existing knowledge for the municipality, such as with Ovar, which has the highest erosion rate (-2.6 m/year), encompassing some of the beaches experiencing the most critical coastal erosion rates.

The CASSIE tool can be applied globally, is freely accessible and serves as an essential tool for addressing coastal dynamics, playing an important role in coastal management. Additionally, it is worth noting that CASSIE’s results are shown similar to those

from previous studies (Aleixo Pinto *et al.*, 2021). Nonetheless, its use should be complemented with the geomorphological settling of the area.

Aknowledgements

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Avaliação do perigo e da exposição à subida do nível do mar em Portugal Continental

Hazard and Exposure Assessment to Sea Level Rise in Mainland Portugal

Andreia Alves da Silva
Jorge Trindade
Jorge Rocha

Resumo

O aumento do nível do mar representa um desafio crescente para as zonas costeiras portuguesas. Este estudo avaliou a exposição das áreas urbanas do território continental português a diferentes cenários de subida do nível do mar (SNM) para os horizontes temporais de 2040, 2070 e 2100, com base no cálculo do Total Water Level, que integra maré astronómica, tempestades, runup, e projeções de SNM (RCP 2.6, 4.5 e 8.5). Os resultados indicam que 23% das áreas costeiras perigosas já são urbanas, podendo atingir 30% até 2100. Foram identificados 12 municípios prioritários para adaptação, evidenciando a urgência de políticas públicas integradas de gestão costeira sustentável.

Palavras-chave: Riscos Costeiros, Subida do Nível do Mar, Ordenamento do Território.

Andreia Alves da Silva
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
CoLAB +ATLANTIC, IPL-ESTM, Peniche, Portugal
Jorge Trindade
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Centre for Global Studies, Universidade Aberta, Lisbon, Portugal
Jorge Rocha
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal

0000-0002-2767-6671
0000-0001-5610-5942
0000-0002-7228-6330

Abstract

Sea level rise (SLR) poses an increasing threat to Portugal's coastal zones. This study assessed the exposure of urban areas along mainland Portugal to sea level rise scenarios (2040, 2070, and 2100) using Total Water Level estimation, integrating tidal, storm surge, runup, and IPCC/NASA SLR projections (RCP 2.6, 4.5, and 8.5). Results show that 23% of coastal hazard zones are currently urbanized, potentially rising to 30% by 2100. Twelve municipalities were identified as high-priority for adaptation. The findings highlight the urgent need for integrated coastal management policies and spatial planning strategies to mitigate risks and promote sustainable coastal resilience.

Keywords: Coastal Risks, Sea Level Rise, Environmental Management.

Introduction

Sea level rise is a global concern, with present and future consequences for coastal areas, populations, and ecosystems. Portugal, as a coastal country (Figure 1), has one of the most dynamic coastlines in the world, making it naturally exposed. Along the 948 km mainland Portuguese coastline, lies the highest population density and the largest share of the country's GDP. The intensification of human occupation along the coast has been evident since the mid-19th century and continues to show a positive trend today. Initially marked by a seasonal dynamic linked to fishing communities, coastal occupation saw a significant increase in urban growth starting in the mid-20th century (Gaspar de Freitas, 2007).

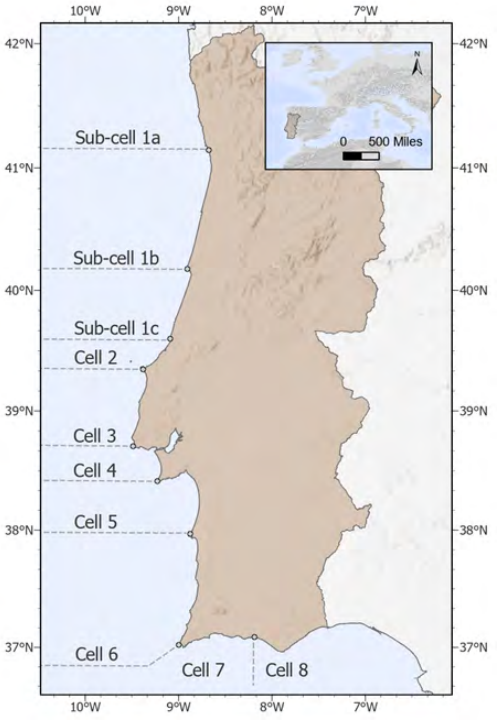

Figure 1. Mainland Portugal and its sedimentary cells.

In addition to the anthropogenic pressure on the coastal areas and the consequences of climate change (e.g. sea level rise and higher frequency of storms), another forcing factor for those areas is the coastal erosion hotspots, induced by the reduction of sediment inflow coming from fluvial systems – which are being trapped by dams built since the 1950s (Dias, 2005). This phenomenon is more pronounced in low-lying, sandy coastal systems.

Sea level rise will impact Portugal's coastline differently, affecting both biophysical communities and urban coastal systems. This study aims to assess the exposure of urban communities to sea level rise in mainland Portugal. To achieve this objective, a methodology for the assessment of exposure of urban cities facing sea level rise scenarios was defined.

Methodology

To understand the impact of sea level rise in coastal areas, this work is divided into three parts. The first aims to define What If Scenarios to Sea Level Rise, based on Total Water Level estimation for three years (2040, 2070, and 2100). The formula aims to obtain the total water level elevation for all the sedimentary cells for mainland Portugal (Figure 1), for each year and scenario, by including the quantification of the sum of i) high astronomical tide (HAT); ii) influence of Storm Surge; iii) runup (50% in rocky coasts; Dodet *et al.*, 2018); and iv) the Sea Level Rise scenarios provided by NASA/IPCC. The SLR scenarios are defined for three RCP projections: 2.6, 4.5, and 8.5, to provide information for a low, intermediate and high emissions scenario, respectively. Regardless of the sea level rise scenario considered, the trend points towards an expansion of the areas affected by coastal erosion, as Ponte-Lira et al. (2016) nationwide projection calculated. These hydrodynamic components are mapped onto sandy, rocky, and anthropogenic systems, using biophysical, altimetric, and land-use criteria.

On the other hand, changes in land use land cover were projected to the analysed years, to understand the potential of exposure in the mainland territory. The input variables were the land use and occupation Portuguese charts (COS), slope gradients, proximity to the urban fabric, proximity to roads, and legal restrictions.

Furthermore, the hazard area and the exposure area were combined to identify the hazard and exposure hotspots for mainland Portugal. Applying a cluster hierarchical analysis and the Ward's method, it was possible to generate an adaptation index for sea level rise.

Results & Discussion

The results (Table 1) show the hazardous area of mainland Portugal, which was 62 km^2 in 2018, and 23% of it corresponds to urban areas that are exposed to coastal hazards, including sea level rise and coastal erosion. The percentage of exposed coastal communities can increase to 30 % of the hazard areas by the end of that century, in the worst-case scenario (RCP 8.5).

	Hazard areas (km^2)	Exposure areas (km^2)
2018	62	14
2100 (RCP8.5)	86	29

Table 1. Total of Hazard and Exposure areas for Mainland Portugal.

A hierarchical classification of clusters has been conducted to assess four types of municipal interventions for adaptation, which are later classified into intervention levels: (I) lower priority; (II) warning municipality; (III-A) higher priority for hazard; and (III-B) higher priority for exposure. The municipalities included in the III-A level in 2018 are four: Vagos, Faro, Olhão, and Tavira. In the year 2040, it is expected that this level will increase the number of municipalities from four to six, with the addition of Ovar and Vila Real de Santo Antonio, for both RCP scenarios considered (2.6, 4.5, and 8.5). In case of higher priority for exposure, at present, there are also four municipalities in that III-B prioritarity level: Póvoa de Varzim, Vila do Conde, Matosinhos, and Grândola. In 2040, Vila Nova de Gaia may become an III-B level, and Loulé in the year 2070, for both RCP scenarios.

Conclusion

Portugal is a coastal country with numerous hotspots for coastal flooding. For a long-term analysis, it is expected an increase in these areas. This work identifies current and future hazard zones for coastal flooding and the urban areas exposed to that hazard. Approximately one-quarter of coastal municipalities of Mainland Portugal are classified as high-priority intervention municipalities (levels III A and B) by the end of the century. These twelve municipalities must adopt strategic political measures to prevent and mitigate potential risks on their coastlines. Political decisions must be informed by comprehensive environmental impact assessments to avoid unintended consequences in neighbouring municipalities, such as those caused by hard engineering solutions.

This prioritization framework serves as a critical tool for decision-making and territorial safeguarding. To minimize the impacts of coastal risks on communities, a rethinking of territorial management is essential. This includes promoting more efficient cities, sustainable spatial planning, and implementing policies that prohibit construction in high-risk areas while preserving safeguarded zones.

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Sistemas de gestão da água nos oásis saariano e o desafio da sustentabilidade face às alterações climáticas: estudo de caso dos oásis de Oued-Noun, sul de Marrocos

The Water Management Systems in Saharan Oases and the Sustainability Challenge in the Face of Climate Change: A Case Study of the Oued-Noun Oases, Southern Morocco

Mohamed Louazani
Abderrafie El Maknissi

Resumo

Este estudo analisa os sistemas tradicionais e modernos de gestão da água nas oásis de Oued-Noun, no sul de Marrocos, avaliando o seu papel na sustentabilidade perante as crescentes pressões climáticas. Os sistemas tradicionais, como as foggaras e canais de derivação, foram soluções eficazes em ambientes áridos, mas têm sido enfraquecidos pela modernização e alterações institucionais. As recentes infraestruturas, como a barragem de Fask e os poços solares, oferecem novas oportunidades e desafios à gestão sustentável. Os resultados destacam a importância de integrar práticas tradicionais e abordagens modernas para preservar o património ambiental e cultural.

Palavras-chave: Oásis, Gestão da Água, Alterações Climáticas, Sustentabilidade, Oued-Noun.

Abstract

This study analyzes traditional and modern water management systems in the Oued-Noun oases of southern Morocco, assessing their role in ensuring sustainability under growing climatic pressures. Traditional systems, such as foggaras and diversion canals, effectively adapted to arid conditions but have been undermined by modernization and institutional shifts. Recent developments, including the Fask Dam and solar-powered wells, present both opportunities and challenges for sustainable water governance. The findings highlight the need to reconcile traditional practices with contemporary management strategies to preserve environmental and cultural heritage.

Keywords: Oases, Water Management, Climate Change, Sustainability, Oued-Noun.

Mohamed Louazani
m.louazani.ced@uca.ac.ma
Research student, Faculty of Arts and Humanities, Cadi Ayyad University, Marrakesh, Morocco
Abderrafie El Maknissi
Professor-researcher, Polydisciplinary Faculty of Safi, Cadi Ayyad University, Marrakesh, Morocco
0009-0004-9954-8582

Introduction

Water is a critical element for the survival of desert-dwelling humans in oases, where communities have shown exceptional adaptability to water scarcity through sustainable techniques that align with the local environment. Significant changes brought by hydro-agricultural developments have led to a decline in traditional communal practices in favor of individualism, impacting the sustainability of water resources. The oases of the Guelmim Ouad-Noun basin exemplify these challenges, confronting substantial environmental and social issues like water scarcity and the effects of climate change.

Materials and Method

This paper explores the traditional methods and systems for managing water resources in the Guelmim Ouad-Noun oases, as well as the changes these systems have undergone in addressing water scarcity. It answers the core question regarding the traditional management forms and systems of water in these oases and their transformations. The study seeks to understand the patterns of traditional water resource management in the Guelmim Ouad-Noun oases, monitor the evolution of these practices, and suggest sustainable strategies to handle water scarcity while preserving environmental and social balance.

The study area

The Guelmim basin, part of the Oued-Noun river basin, is situated on the southern foothills of the Western Little Atlas, covering roughly 6,793.89 km². It is bordered to the north by the Western Little Atlas (Anti Atlas) mountains, to the south by the Gir and Tissa mountains, to the west by the Atlantic Ocean, and to the east by the Banis plains. Administratively, it falls within the Guelmim province of the Oued-Noun region, including various urban and rural communities such as the urban communities of Guelmim and Bouizakarne.

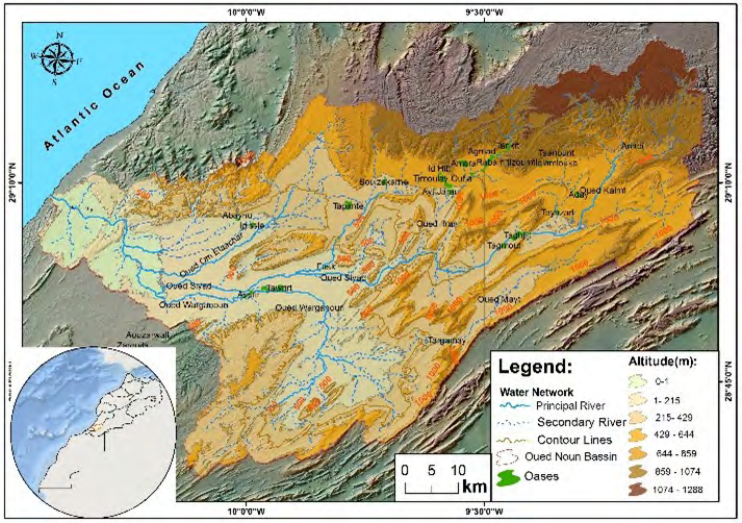

Figure 1. Location of the Oued-Noun Oases
Source: compilation based on the division of major river basins in Morocco and a 30-meter digital elevation model SRTM.

The Guelmim basin is notable for its topographic diversity, with units divided into highlands (mountainous areas) and lowlands. Geologically, it shares the characteristics of the Western Little Atlas, with significant geological variations. From a climatic standpoint, the study area's position contributes to an arid climate, (BEN BRAHIM M, 2003) influenced by dry Saharan winds from the south, while the Atlas range northwards blocks incoming moisture, leading to a rainfall pattern dominated by scarcity, with an annual average not exceeding 190 mm between 1981 and 2019, alongside considerable variability in annual, seasonal, and monthly precipitation. Natural and human-induced factors, including intense and unregulated exploitation, have led to a decrease in the flow from springs and foggaras (**khetaras**), with an increase in the depth of the groundwater table. Water, therefore, stands as the greatest challenge for both the local population and the state, given the desert environment where most groundwater is non-renewable. (Belqadi A. 2013)

Traditional Water Management

The inhabitants of the Ouad-Noun oases have long focused on managing water scarcity, demonstrating ingenuity in creating adaptive techniques that harmonize with the local environment. This has enabled them to produce a legal and equitable framework for managing water resources for centuries, ensuring land irrigation and thus the persistence of the oases.

Traditional Water Sources

- **Springs(Ain):** A primary source of groundwater, is used for agricultural activity, irrigating up to 1117 hectares (Chmourk, E-M.2011) despite recent declines in flow. Several springs are located along the banks of the Oued wargnoun and Oued Sayad, as well as their tributaries. These springs are characterized by their consistent flow and ease of use, although their discharge rates vary.They are primarily utilized for irrigating agricultural lands. Among them are “Ain Agadir Mkourn” in the Tagmout Oasis, “Ain Tofagho” in the Tinzert Oasis, “Ain Tajnant” and “Oued Wargnoun” in the Tighmert Oasis, as well as “Ain Bouizakarne” and “Ain Tagant.

- **khetaras:** An effective method for exploiting groundwater, using underground channels to minimize evaporation. The Guelmim basin has around 216 foggaras, with varying flows, from as high as 44 liters per second to as low as 1.5 liters per second. (Oasis Preservation and Development Program for the Southern Provinces POS .2009)

Structurally, a khetara is divided into three main parts:

1. The Supply Zone: Known locally as **«Ras El Khetara»** this area includes the first and deepest wells, which contain the springs that feed the khetara system.
2. The Water Channel: These are the underground passages that carry water from the supply zone downstream. This section is divided into specific intervals called «Qantara,» which refer to the distance between two consecutive wells, usually no more than 40 meters apart.
3. Distribution Channels: This network ensures the efficient delivery and allocation of water. It includes a main central canal (Targa) connected to secondary canals (Asaro), which then branch into smaller tertiary canals (Aginan). It’s important to note that the canals are often named after the beneficiaries, such as the tribe, community, or family they serve, or the specific irrigated area they supply. (Oudada M, Azdi F. 2018)

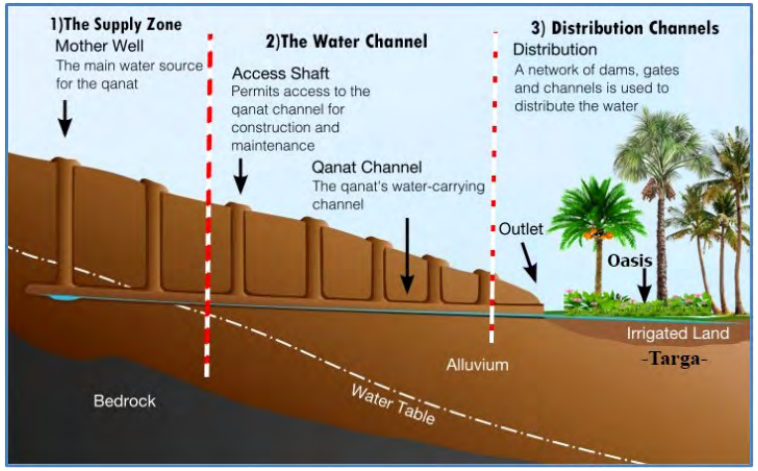

Figure 2. Simplified Diagram of khetaras

- **Diversion Dams and Can :** Constructed to capture floodwater and distribute it through a network of canals for traditional farming. (Al-Sharkawi A. 2005).

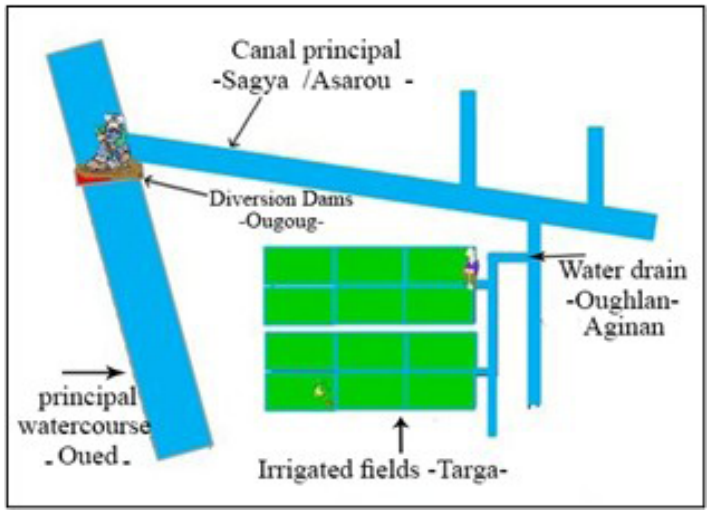

Figure 3. Simplified Diagram of a Canal
Source: (Ouhajou, L.1996) (modified)

Figure 4. The Diversion Dam at Taghjijt Oasis
Source: Cliché Personal 2019

Customary Water Regulation

- **Turn System:** A system based on alternating water distribution according to individual contributions to infrastructure.
- **Community Institution:** A traditional body that organizes irrigation operations and manages water-related disputes.
- **Customary Penalties:** Applied to violators to ensure compliance with water management rules, either material or in-kind, like community service such as cleaning canals or removing contaminants from water reservoirs. (El-Talib Mahand A.2016)

Figure 5. Technique for Water Distribution (Tanast)

Discussion

Modern Transformations in Water Management: The introduction of modern techniques in water resource management has been among the most significant changes:

- **Modern Dams**
  Fask Dam: As part of the new development plan for the southern regions, launched in February 2016 in Dakhla, the

Fask Dam, located downstream of the Sayad Basin, is set to become the largest and most important water facility in the Guelmim Basin and the southern regions. This strategic project, with a total budget of 1.5 billion dirhams in partnership with Qatar, is expected to significantly enhance water reserves in the medium and long term.

The Fask Dam is located 30 km east of Guelmim and 8 km east of the Fask community center. It is being constructed on the Oued Sayad over a 48-month period (2017–2021). With a capacity of 79 million cubic meters, the dam will manage a water reserve of 19 million cubic meters, protect water resources in the region, and reduce water waste from the floods of several wadis that flow into the Tofilit Ait Hammad plain (Fask community). This plain is one of the richest agricultural areas in the region. The dam will also irrigate the agricultural perimeter downstream, including the Guelmim plain, supply drinking water to urban and rural centers in the region, enhance the groundwater table, and protect against flood risks.

Following recent rainfall in the Guelmim Oued-Noun Basin, the Fask Dam reservoir received approximately 10.5 million cubic meters of water by 6:00 PM on Sunday, September 8, 2024, increasing its storage rate to 12.65%. This project is also expected to boost the tourism and employment sectors, particularly for youth, providing a strong economic dynamic to the region. (Ministry of Equipment and Water of Morocco,2024)

Figure 6. Location of the Fask Dam
Source: Noufel El Majdoubi, 2024

- **Collective and Individual Well:**

Based on the data from the figure 10, farmers have worked tirelessly to find new water sources for irrigating agricultural plots within the oases after the springs dried up. Many oases in the Guelmim Oued-Noun Basin have experienced the depletion of springs and foggaras that once supplied water to these areas. These traditional sources have now been replaced by modern wells, which have been drilled by local authorities and water user associations in the oases of the Guelmim Basin.

Each canal now has its own well, managed by an association responsible for its operation and maintenance. This represents a shift in irrigation and water management systems, as the traditional canal networks have been preserved while the wells have been equipped with solar energy. Water is rented to farmers at a fixed rate, depending on their capacity, which generates significant financial resources for the associations.

These funds are used for investments, exploring new methods to ensure the sustainability of water resources, and managing canal repairs and periodic cleaning.

Below are examples of canal layouts in some oases, as well as a map showing the distribution of these new wells, which are now used for oasis irrigation after the foggaras dried up.

Figure 7/8. New Wells at Taghjijt Oasis, Ain El Ansar with Solar Energy at Ifrane
Source: Mohamed LOUAZANI, 2023

Figure 9. Well and Reservoir Equipped Oasis
Source: Mohamed LOUAZANI, 2023

Solutions and Recommendations for Water Resource Sustainability

Given the profound changes in water resource exploitation in the oases and the resulting environmental degradation, there is a need for serious consideration of organizing water use based on scientific principles that focus on optimizing available resources while ensuring their sustainability:

- Raising awareness among farmers about the importance of adopting drip irrigation within the oases to conserve and rationalize water use.
- Working on legislating the production of market crops that consume significant water resources and are not native to the area.
- Intensifying agricultural research to develop techniques for conserving water resources.
- Organizing the exploitation of groundwater with an emphasis on collective management.
- Creating an accurate database on successful water management projects.
- Granting licenses for the purpose of drilling new wells for the benefit of water user associations for agricultural purposes.
- Revaluing cultural heritage with an emphasis on collective water management.
- Supporting and encouraging self-initiated projects by some farmers to preserve natural heritage, with framing, training, and providing technical assistance.
- Coordinating efforts and programs among stakeholders concerned with the development of oasis areas.

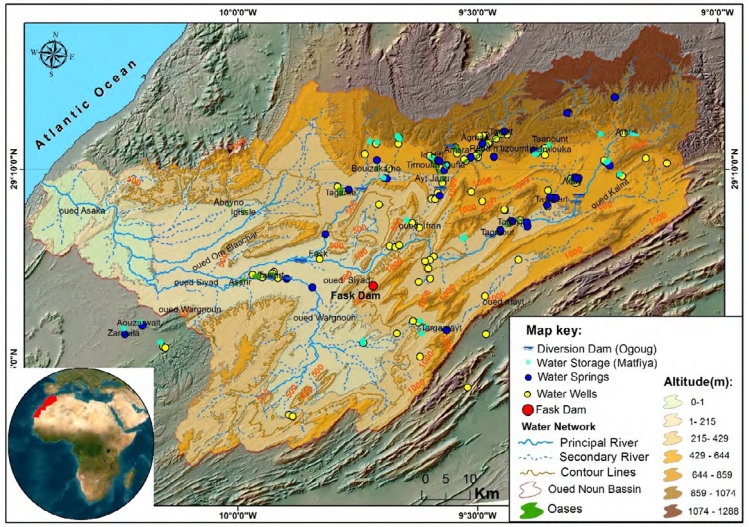

Figure 10. Distribution of New Wells within the Oases
Source: Field Visit, 2023

Conclusion

The oases of the Guelmim Oued-Noun Basin face growing challenges due to water scarcity and socio-environmental changes. While traditional water management systems have declined, the introduction of modern techniques such as dams and solar-powered wells offers promising solutions. However, the sustainability of water resources depends on coordinated efforts among stakeholders, increased awareness of sustainable practices, and the revival of solidarity and collective management values.

In 2020, several Moroccan oases, including those in the city of Errachidia, saw their foggaras recognized as UNESCO World Heritage Sites, acknowledging them as tangible cultural heritage. This recognition serves as an incentive for other Moroccan oases to register their water-related heritage with UNESCO. Foggaras play multiple roles, such as reducing water evaporation and limiting rural migration, as local communities are reluctant to abandon their lands as long as these systems remain functional.

There is a need to explore new ways of living without compromising ancestral heritage, combining traditional foggaras with modern irrigation methods. While both systems have their merits, the traditional foggaras were more sustainable, whereas modern techniques often lead to overexploitation of water resources, resulting in declining water reserves.

Government policies providing aid to farmers have had a noticeable impact on the region. However, given the challenges of declining groundwater levels and the depletion of springs and foggaras, farmers may face difficulties in sustaining these benefits without long-term policies that promote more efficient and resilient water use practices.

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Risco de cheias em Moçambique: estratégias comunitárias para a redução da vulnerabilidade a partir de dois estudos de caso

Flood risk in Mozambique: communitarian strategies for vulnerability reduction from two case studies

Ricardo Acácio Xavier
Pedro Pinto Santos
José Manuel Mendes

Resumo

Este artigo analisa o risco de cheias e as estratégias comunitárias de redução da vulnerabilidade nos distritos de Chinde e Mopeia, Província da Zambézia, Moçambique. Através de entrevistas, revisão bibliográfica e análise estatística, foram identificados fatores económicos, infraestruturais, políticos e individuais que contribuem para a vulnerabilidade. Os resultados revelam capacidade institucional limitada e exposição persistente em zonas de risco, apesar dos sistemas de alerta precoce. O estudo destaca abordagens comunitárias proativas, baseadas nos comités locais (CLGRD) e nos Centros de Recursos e Usos Múltiplos (CERUM), reforçando a liderança tradicional e a integração do conhecimento local na gestão de riscos.

Palavras-chave: risco de cheias; vulnerabilidade; adaptação comunitária; Moçambique; resiliência.

Ricardo Acácio Xavier
ricardoacaciox@gmail.com
Institute for Interdisciplinary Research, University of Coimbra; Casa Costa Alemão - Pólo II, Coimbra, Portugal
Pedro Pinto Santos
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal, Associate Laboratory TERRA, University of Lisbon, Portugal
José Manuel Mendes
Centre for Social Studies, Faculty of Economy, University of Coimbra, Coimbra, Portugal

0000-0001-9785-0180
0000-0003-3602-9756

Abstract

This paper examines flood risk and community vulnerability reduction strategies in Chinde and Mopeia districts, Zambezia Province, Mozambique. Using interviews, bibliographic review, and statistical analysis, it identifies economic, infrastructural, political, and individual factors contributing to vulnerability. Findings reveal limited institutional capacity and persistent exposure in flood-prone zones, despite existing early warning systems. The study highlights community-based approaches, emphasizing proactive adaptation through local committees (CLGRD) and Centres for Resources and Multiple Uses (CERUM). Strengthening traditional leadership and integrating community knowledge into disaster risk management can enhance resilience and sustainable adaptation to recurrent flood events.

Keywords: flood risk; vulnerability; community adaptation; Mozambique; resilience.

Introduction

In recent years, the world has witnessed a growing increase in disaster risk resulting from natural processes like river floods. The impact of these phenomena – depending on their magnitude and the socioeconomic and technological capacities of individuals, communities, and nations (Cutter et al., 2003; Mendes, 2010; Santos et al., 2022) – can lead to a range of consequences including displacement and permanent relocation.

These consequences are characterized both by their global nature and their uneven distribution, as well as by the increasing frequency and intensity of such natural phenomena at local, regional, and global levels. This implies that disaster risk is no longer solely relevant from the perspective of those directly affected but has instead become a global concern (Mattedi, Marcos & Brikner, 2019).

Although all countries and social strata are already experiencing the effects of these phenomena, less developed countries are suffering the most severe consequences, despite contributing little to the worsening of the flood triggering factors, like rainfall and storm patterns aggravated by the warming of the Globe. Therefore, it is urgent that such countries and their local communities strengthen their response and adaptive capacity.

Response and adaptive capacity, along with exposure and propensity to loss – commonly referred to as susceptibility – are three main characteristics that describe vulnerability (Birkmann et al., 2013). Specifically in regard to floods – where indirect impacts are particularly relevant in non-inundated areas in Africa – individuals, communities, and assets become vulnerable when they are unable to adequately anticipate, withstand, and recover from disaster threats, or when a range of elements they rely on – such as housing, water sources, crops, livestock, the economy, and employment – are placed at risk by flood-related physical processes, accompanied by political, socioeconomic, or environmental processes (Venton & Hansford, 2006; Yusmah et al., 2020). The intersection between vulnerability and hazardous processes increases the likelihood that a threat will result in harm to these people or systems.

Mozambique's legal and institutional framework for responding to calamities caused by natural processes has been strengthened in recent years (INGC, 2013, 2017). However, significant gaps and resource constraints remain, particularly in addressing the root causes of disasters through preventive measures. As a result, recovery planning often falls short of being effective, sustainable, and respectful of local customs and subsistence needs of affected communities (Jacobs and Almeida, 2020).

Research Questions and Purposes

The research aimed to assess the vulnerability and adaptive capacity of communities regarding the risk of floods, inundations, and climate change in the districts of Chinde and Mopeia, located in Zambézia Province, Mozambique, at the mouth of the transnational Zambeze river.

This purpose was derived from the following research questions:

- Why do so many people continue to fall victim to floods and inundations despite the existence of an operational warning and alert system for flood risks in Mozambique?
- Given the various intervention strategies including the use of new technologies, technical capacity building, and institutional coordination both nationally and among Southern African countries in early warning signals what has been failing in disaster risk reduction strategies?
- Finally, what factors lead communities residing in flood-prone areas to persist in living and conducting their activities in these locations (see Figure 1) rather than relocating to the safer areas designated by authorities?

Vulnerability Diagnostic of the Mopeia and Chinde Communities

Local interviews, bibliographic review and statistical analysis of official and geographical data allowed to identify four types of factors that influence vulnerability in Mopeia and Chinde.

A total of 72 interviews were conducted: 31 in the Mopeia district, 36 in the Chinde district, 1 in the Zambeze province capital (Quelimane) and 4 in the contiguous Caia district (at the south margin of the Zambeze river, Sofala province). The interviewees included public managers, officials, members of the Local Disaster Risk Management Committees (CLGRD), community leaders and the respective residents, i.e., people living in flood-prone areas and those living in resettlement neighbourhoods (the reason why some interviewees are located outside the Chinde and Mopeia district, as the Caia district, for example).

Apart from the analysis of the communitarian strategies of local communities, the interviews allowed for the design and implementation of a socioeconomic matrix of vulnerability in each district, through the application of a score-card system, from 0 to 5, to the following dimensions: agriculture, fishing, households, commerce, water sources and coal production. Both communities score 20 in a theoretical range of 0 to 30. Compared with droughts, soil loss and plagues, flooding surges with the highest vulnerability scores.

Combining the distinct techniques and methods of research, the following four vulnerability factors were saliented:

- Economic factors include poverty resulting from dependence on fragile livelihoods, lack of opportunities for access to credit, access to employment and to public investment; failure of resettlement programs (Figure 2); and the persistence of local customs.

Figure 1. Adaptation of residential houses in the flood prone areas in the study area, as a strategy to avoid relocation and loss of proximity to livelihood-essential resources.

Figure 2. Resettlement houses in the neighborhoods of "24 de Setembro" (Mopeia, top) and "Matilde" (Chinde, bottom)

- Infrastructural factors include lack of basic health, education, and sanitation services; insufficient and fragile water infrastructure (including inadequate roads and access, dams, dikes, and reservoirs); and rapid urbanization.
- Political factors include wars and successive political-military conflicts, which lead to temporary displacement and the destruction of infrastructure, as well as weak institutional coordination and cooperation both nationally and among countries.
- Individual factors include low levels of educational qualifications and limited access to information, weak public and institutional awareness, and a shortage of skilled human resources.

Communitarian Strategies for Vulnerability Reduction

Interviews with community leaders, decision makers and disaster risk practitioners at distinct levels of competence, defend a change from a reactive approach to a proactive one (Figure 3), that is sustained in an institutional regional level response based on Action Plans, and a more local – although vertically connected – approach that addresses risk preparedness and sustainable livelihoods, without the need for relocation (Figure 2).

Agriculture is the key activity for the subsistence of local communities, although some erroneous practices should be avoided, that increase soil loss and dependence on monoculture. Accessibility and energy supply are another key elements in a sustainable and resilient planning for vulnerability reduction.

Whenever relocation is unavoidable – and recognizing the extremely difficult challenge of reducing vulnerability drivers (low income, weak health and educational services and low economic dynamism) –, it becomes crucial to act on exposure at the level of urban and spatial planning, integrating various scales and administrative levels of management. Land management guidelines at provincial level need to be complied with at local level, with clear accountability for non-compliance from the defined norms, in order to avoid repeating mistakes of re-occupying incompatible areas for housing purposes.

The initiative for the community preparedness, however, still relies on a top-down mechanism, reflected on the legal creation and capacitation of two essential local-level bodies, the Centre for Resources and Multiple Uses (CERUM) and the Local Committees for Disaster Risk Management (CLGRD).

These bodies (CERUM and CLGDR) arise within the scope of the so-called 'precautionary principle,' proposed by Giddens (2000, p. 39), which, according to Mendes (2015, p. 36), is based on the surveillance system, alert system, monitoring, and knowledge exchange, as well as the adoption of positive measures and initiatives for managing situations of high uncertainty and advancing knowledge.

Based on this principle (Figure 3), the CERUM are tasked with working on the training and capacity-building of CLGRD and small and medium-sized enterprises on best practices that can help reduce vulnerability to disaster risk through actions that promote mitigation and adaptation. Meanwhile, CLGRD, in partnership with community authorities, train individuals and communities (both urban and rural) on how to deal with disaster risks and implement adaptation strategies in response to the increasing frequency of natural disasters and their impacts on communities (INGC, 2012).

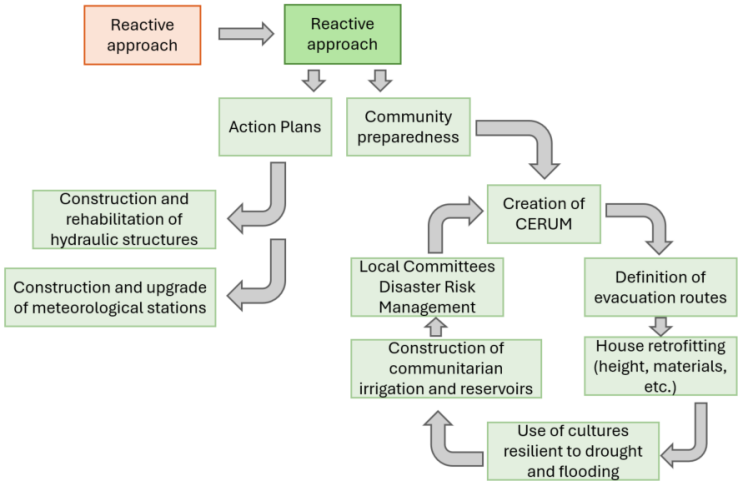

Figure 3. The change from a reactive to a proactive response in adaptation and mitigation of flood risk disasters.

Traditional and formal leadership mechanisms

Leadership in indigenous local communities is another key element to consider in disaster risk management in Mozambique.

According to Lourenço (2008), local community authorities and the political-administrative and spiritual power (inter)related to them have been and continue to be important agents of social cohesion and cultural identity, legitimising authority and regulating relations between the members of their community and with other surrounding communities, as well as with the environment. These aspects make community authorities highly respected and regarded locally. However, although Decree-Law 15/2000 gives them certain political-administrative powers, they are legitimised by the communities, which allows them to act as local political actors coordinating small activities (managing and resolving small social conflicts and in the processes of organising society) and assisting formal state institutions in coordinating disaster risk management and risk reduction activities in terms of raising awareness among communities and receiving displaced people in case of need.

It's important to note that among the community authorities there are two categories: community leaders, who have political-administrative functions; and traditional leaders (religious leaders) who look after spiritual matters. In this local political system, it is interesting to note that every spiritual leader is also a community leader, but not every community leader is a traditional (religious or spiritual) leader.

In general, community leaders have community and spiritual leaders in their court or council of elders whom the communities recognise as having spiritual power. Community members attach themselves to their power and ability and, according to local beliefs, it is believed that they can influence disaster control, namely 'by promoting or diverting the area of occurrence of natural phenomena' (Matusse, Barros, & Barros, 2009).

Final Remarks
Main contributions

The mapping of flood vulnerability factors in each district will assist local decision-makers in making informed decisions. The research included some training and capacity-building of Local Committees for Disaster Risk Management (CLGRD) and community leaders, which is expected to broaden awareness on climate issues (causes, impacts, and response strategies). The research prompts reflection on the history, values, cultures, practices, and customs that are often overlooked in the processes of relocating communities from risk zones to areas considered safe.

Limitations encountered during the research

Main limitations consisted of issues in accessing databases and documents in institutions dealing with disaster risk (INGD, INAM, ARA-Zambeze). Moreover, logistically, the lack of access roads prevented the visit to more communities in the selected districts. Finally, linguistic limitations of some communities, who only speak local languages, required the restructuring of techniques and data collection methods (resorting to the local language in some cases).

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Perfis de risco de perigos costeiros em Portugal Continental à escala da freguesia

Risk profiles of coastal hazards in mainland Portugal at the civil parish level

Susana Pereira
Jorge Trindade
Andreia Alves da Silva
Pedro Pinto Santos
Eusébio Reis
José Luís Zêzere

Resumo

Este estudo avalia o risco costeiro em Portugal continental ao nível da freguesia, combinando indicadores de perigosidade, exposição e vulnerabilidade social sob diferentes cenários de subida do nível do mar (SLR) para 2040, 2070 e 2100. Os resultados mostram uma expansão significativa das zonas de risco e das áreas urbanas expostas, sendo a exposição o principal fator de aumento futuro do risco. A análise de clusters identifica perfis de vulnerabilidade distintos, destacando a importância de integrar estes indicadores na gestão costeira. As conclusões apoiam políticas adaptativas e equitativas que reforcem a resiliência e reduzam os riscos associados à SLR.

Palavras-chave: subida do nível do mar; risco costeiro; vulnerabilidade social; exposição; resiliência.

Susana Pereira
Centre of Studies in Geography and Spatial Planning, Geography Department, Faculty of Arts and Humanities, University of Porto, Porto, Portugal
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Jorge Trindade
Centre for Global Studies, Aberta University, Lisbon, Portugal
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Andreia Alves da Silva
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal

Abstract

This study assesses coastal risk in mainland Portugal at the civil parish level, combining hazard, exposure, and social vulnerability indicators under different sea-level rise (SLR) scenarios for 2040, 2070, and 2100. Results reveal that both hazard zones and exposed urban areas are projected to expand considerably, with exposure emerging as the main driver of future risk. Cluster analysis identifies differentiated vulnerability profiles across regions, emphasizing the importance of integrating these indicators into coastal management frameworks. The findings support the design of adaptive and equitable policies to enhance resilience and reduce SLR-related risks.

Keywords: sea-level rise; coastal risk; social vulnerability; exposure; resilience.

Pedro Pinto Santos
Eusébio Reis
José Luís Zêzere
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Associate Laboratory TERRA, University of Lisbon
Instituto Superior de Agronomia, Lisbon, Portugal

0000-0002-9674-0964
0000-0001-5610-5942
0000-0001-9785-0180
0000-0001-8367-1835
0000-0002-3953-673X

Introduction

Coastal areas are prone to a set of hazards which tend to accentuate under sea level rise (SLR) scenarios. The spatial and temporal distribution of risk, and the consequent losses, in such dynamic areas are explained by complex interactions of human and natural factors, commonly represented as hazard, exposure and vulnerability.

In this article, the assessment of coastal risk due to SLR is represented through a risk index at the civil parish level in mainland Portugal, utilizing scenarios of coastal overtopping and sea-level rise expressing hazard, current exposure, and social vulnerability.

Study Area

The mainland Portuguese coast extends for 987 km, morphologically as diverse as beaches, barrier islands, estuaries, lagoons and cliffs can be found, with varying sedimentary budgets (Figure 1). The coast varies in terms of exposure to storms: the west coast is hit by powerful waves from the North Atlantic, while the south coast is less exposed, with weaker waves. The waves that hit the coast also differ in height and period, decreasing towards the south in height (1.7 to 2.2 m) and period (6.6 to 7.2 seconds). On the south coast, the waves are around 1 m high and have a period of 4.7 seconds (Pinto *et al.*, 2020).

Administratively, the shoreline is touched by 138 civil parishes, aggregated in 52 municipalities. In those municipalities live about ¾ of the c. 10 million Portugal's inhabitants. The distribution of the population is, however, uneven, with the northern coast until Lisbon being more densely – and even so, unevenly - populated than the remaining western Atlantic and southern coast. Major cities along the coast include Porto, Aveiro, Figueira da Foz, Lisbon, Setúbal and Faro (east of Olhos de Água in Figure 1).

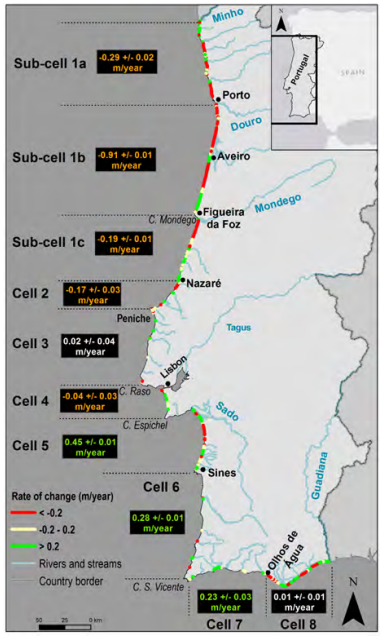

Figure 1. Sedimentary cells of the mainland Portuguese coast, and shoreline rate of change (m/year) as defined in Ponte Lira *et al.* (2016).

In this context, the historical rate of SLR of 2.1±0.1 mm/year between 1977 and 2000 alone was already concerning, to which it adds a projection of mean SLR of 1.14 m by 2100 (Antunes, 2019).

Input Data for Sea Level Rise Risk Profiles

The INFORM risk index-alike formulation was adopted (Marin-Ferrer *et al.*, 2017) considering, however, the classic risk components of hazard (H), exposure (E) and vulnerability represented by social vulnerability (SV) (Eq. 1).

$$\text{SLR risk} = (H^{1/3}) \times (E^{1/3}) \times (SV^{1/3})$$

Hazard

Sea level rise hazard assessment was based on the extent of the intermittent floodable area, where SLR hazard corresponds to the spatial extent of a potentially damaging event with a given magnitude within a specified period and a given location. SLR hazard considers the spatial propensity of a coastal area to be flooded by coastal buildup area overtop or system overwash based on medium- and long-term SLR scenarios (Trindade et al., 2023). The following scenarios were considered: future shared socioeconomic pathways SSP1-2.6, SSP2-4.5, and SSP5-8.5, for the years 2040, 2070 and 2100.

As an illustrative example of result, the current flooded area of 100.66 km^2 will increase 23.5 km^2 from 2011 to 2040 in the SSP5 scenario.

Exposure

The 2011 information on the residential buildings was used to estimate the number of inhabitants and buildings in hazardous areas (INE, 2011), by applying a dasymmetric distribution of residents, that distributes polygonal Census block data to point-type data corresponding to each building, considering the no. of households and the vacant ones (Garcia et al., 2016). The residential population exposed in 2011 was 29,174, which is expected to reach 41,382 by 2100 under SSP5.

Social vulnerability

For the cartographic expression of SV, the conceptual model of Mendes *et al.* (2010, 2019) and Santos *et al.* (2022) was adopted, based on the SoVI statistical steps of Cutter *et al.* (2003). The SV data used refers to a previous analysis done at the civil parish level, with the available data at the time, the 2011 Census (Santos et al., 2022) From an initial set of 24 variables, the final SV principal component analysis retained 15, expressing 4 principal components, interpreted as drivers of SV: PC1 – Age and educational level, PC2 – Economic condition and social dynamism, PC3 – Unfavourable social contexts, and PC4 – Uprooting and internal mobility (Table 1).

Variable	PC1	PC2	PC3	PC4
MeanAge	*0.95*	0.01	-0.09	-0.03
Fam65	***0.91***	0.04	0.03	-0.02
WomAct	***-0.86***	0.25	-0.11	-0.04
Illiter	***0.80***	-0.25	0.17	0.01
PopChan	***0.69***	-0.35	0.14	-0.06
HighEdu	-0.39	***0.76***	-0.19	-0.08
SociVal	-0.16	***0.76***	-0.22	-0.17
5yrMuni	0.03	***0.75***	0.03	0.29
Foreign	-0.10	***0.69***	0.34	0.07
OverCro	-0.48	-0.09	***0.73***	0.11
CarUsag	-0.34	0.01	***-0.66***	-0.09
BasInfr	0.40	-0.30	0.45	0.14
SchLeav	0.04	0.06	0.30	-0.20
OtheMuni	-0.19	0.08	-0.19	***0.84***
Commut	0.18	0.03	0.26	***0.74***
Cardinality	+	Inc.[a]	+	+
% of variance explained	33.5	13.3	11.6	8.0

Table 1. Rotated component matrix of the 2011 SV principal components and the respective explicative variables (loading ≥0,6) in italics and bold. For a description of variables' definition, please see Santos *et al.* (2022) and Annex 1.

Sea Level Rise Risk Profiles

Apart from the calculation of SLR risk, a cluster analysis of the min-max normalized scores of hazard, exposure and social vulnerability was performed. This classification method allowed to understand the existence of distinct profiles of SLR risk, aggregating civil parishes that share the same patterns of H, E and SV (Figure 2).

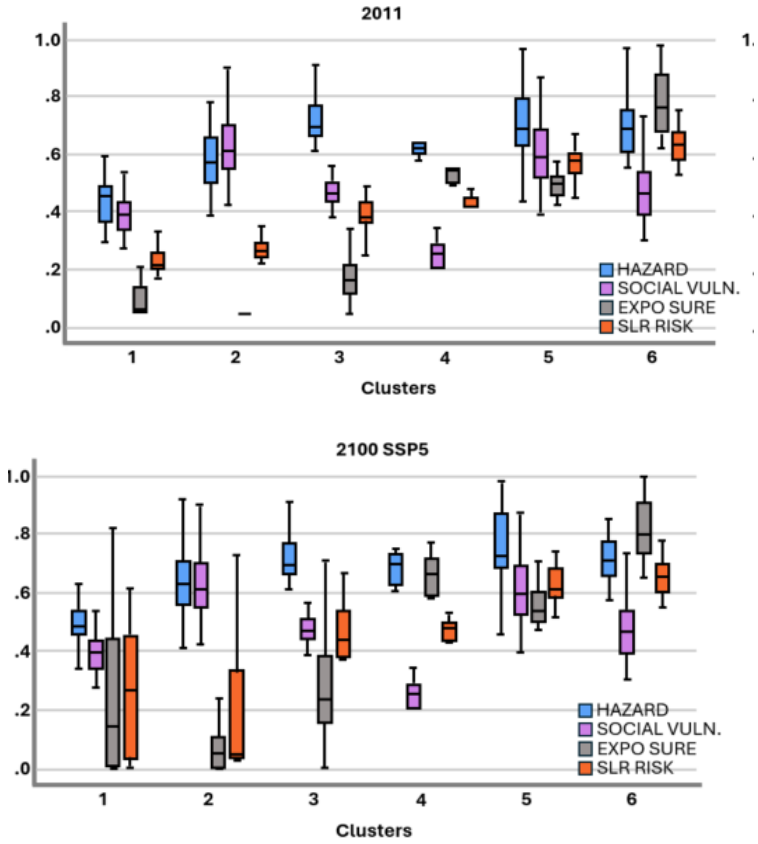

Figure 2. Clusters statistics of SLR risk index for present and future worst-case scenario (2100) under SSP5.

Clusters 1 (24 civil parishes) and 2 (47), for example, gathers the territories with lower risk: the civil parishes in cluster 1 have the lowest average exposure and 10 out of its 24 civil parishes are located in sedimentary cell #7 (cf. figure 1). Although with low risk, cluster 2 represents the highest SV scores found.

High hazard is particularly found in clusters 3 (13 civil parishes) and cluster 5 (19), They are located sparsely along the coastline, except in sedimentary cells #1c, #2 and #7. Clusters 4 and 6 are characterized by low scores of SV.

Conclusion

In this work, we attempted a new method of representing current and future risk to sea level rise, using scenarios of territorial expression of hazardous coastal processes, and of human exposure and built heritage. This is one of the innovative aspects of the methodology in supporting coastal decision-makers. The social vulnerability component cannot be represented in future scenarios due to the complexity of predicting socio-economic and demographic characteristics in the future.

Cluster analysis of risk components identified exposure as a key element in explaining future SLR risk. Accordingly, it is fundamental that mitigation and adaptation policies focus on complementing natural hazards risk management measures with multi-sector wider institutional policies that reduce the PCA-identified drivers of social vulnerability and build resilience and adaptative capacity.

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Annex 1. Variables used in the final model of the social vulnerability assessment.

Variable	Description
MeanAge	Mean age of the resident population (years)
Fam65	Proportion of single person private households with a person aged 65 years old and over (%)
WomAct	Women activity rate (%)
Illiter	Illiteracy rate (%)
PopChan	Variation ratio of resident population between Census (e.g. 2001-2011) (%)
HighEdu	Proportion of resident population with higher education completed (%)
SociVal	Proportion of professionals socially more valued (%)
5yrMuni	Proportion of resident population that 5 years before inhabited outside municipality (%)
Foreign	Proportion of resident population of foreign nationality (%)
OverCro	Proportion of overcrowded living quarters (%)
CarUsag	Proportion of car usage on daily journeys (%)
BasInfr	Proportion of conventional dwellings without at least one basic infrastructure (%)
SchLeav	School leavers rate (%)
OtheMuni	Proportion of resident population that works or studies in other municipality (%)
Commut	Average time spent on commuting (min) of the employed or student resident population

Cartografia da sensibilidade à degradação dos solos na bacia hidrográfica do oued El Abid: aplicação do modelo MEDALUS

Mapping Sensitivity to Land Degradation in the Wadi El Abid Watershed: A MEDALUS-Based Assessmentl

Chaima Imam
Mohamed Chaibi
Fatima El Bchari

Resumo

A degradação do solo representa um dos principais desafios ambientais na bacia hidrográfica do Oued El Abid, em Marrocos. A sensibilidade à degradação do solo foi avaliada utilizando a metodologia MEDALUS, integrada com os Sistemas de Informação Geográfica (SIG). Quatro índices, nomeadamente clima, solo, vegetação e gestão, foram combinados para produzir um índice global de sensibilidade. Os resultados indicam que mais de 60% da bacia apresentam vulnerabilidade que varia de "frágil" a "crítica", principalmente devido às condições de seca, à baixa cobertura vegetal e às pressões antrópicas. Esta abordagem integrada constitui uma ferramenta eficaz para mapear e promover a gestão sustentável das terras em áreas sensíveis.

Palavras-chave: Degradação do solo; Sensibilidade ambiental; Metodologia MEDALUS; Bacia hidrográfica do Oued El Abid.

Abstract

Soil degradation represents one of the main environmental challenges in the Oued El Abid watershed, Morocco. The sensitivity to land degradation was assessed using the MEDALUS methodology integrated with Geographic Information Systems (GIS). Four indices, namely climate, soil, vegetation and management, were combined to produce a global sensitivity index. The results indicate that more than 60% of the basin exhibits vulnerability ranging from "fragile" to "critical," mainly due to drought conditions, low vegetation cover and anthropogenic pressures. This integrated approach provides an effective tool for mapping and promoting sustainable land management in sensitive areas.

Keywords: Land degradation; Environmental sensitivity; MEDALUS; Oued El Abid watershed.

Chaima Imam
Mohamed Chaibi
chaibimohamed@gmail.com
Fatima El Bchari
Département of Géographie, Faculté Polydisciplinaire, Université Cadi Ayyad, Safi, Maroc

0009-0000-3070-9764
0000-0003-0942-1015

Introduction

La dégradation des sols constitue une menace majeure pour l'humanité et l'environnement au XXIe siècle, à toutes les échelles (World Bank, 2002 ; Vieira et al., 2015). Elle engendre des crises écologiques, alimentaires, socio-économiques et politiques (Vieira et al., 2015). Le phénomène de désertification, tel que défini par le PNUE (1991) et le CNUED (1992), affecte les zones arides, semi-arides et subhumides sèches. Il résulte de multiples facteurs climatiques, anthropiques, édaphiques et biotiques (UNCCD, 1994 ; Mokhtari, 2016). Ce processus entraîne des transformations du couvert végétal et des sols, allant jusqu'à leur disparition, où la productivité biologique devient quasi nulle. La lutte contre la désertification et la dégradation des terres est une priorité internationale, touchant plus d'un milliard de personnes (Rubio & Recatala, 2006) ; environ 25 % des terres mondiales sont gravement dégradées (UNCCD, 2015). Ce phénomène est amplifié par les sécheresses répétées, la croissance démographique et la surexploitation des ressources naturelles, posant un défi durable pour les décideurs, les populations locales et les chercheurs.

Bien qu'il soit mondial, certaines régions comme le bassin méditerranéen, le Sahel, la Mésopotamie et la région du loess en Chine sont particulièrement critiques (Dregne, 2002). En Afrique, 46 % des terres sont affectées par la désertification. Au Maroc, cette problématique touche plus de 90 % du territoire en raison du climat aride et de sols vulnérables à l'érosion (Ghanam, 2003 ; Hammouzaki, 2013). L'exploitation excessive des ressources par les populations rurales, souvent en réponse à des conditions de vie précaires, aggrave cette dégradation (Ghanam, 2003 ; Ait Lamqadem et al., 2018). Les outils géospatiaux et la télédétection permettent désormais une surveillance rapide et efficace des terres, complémentaire aux études de terrain (Gao et al., 2008 ; Bakr, 2012). Des approches variées, intégrant des indicateurs biophysiques et anthropiques, ont été développées pour identifier les zones dégradées, notamment celles proposées par FAO/UNEP, DSPIR, MEDALUS, LADA et DRAST (Xu, 2009 ; Lamchin, 2016).

La méthode MEDALUS, en particulier, est reconnue pour évaluer la sensibilité à la désertification en raison de sa simplicité et flexibilité. Elle a été appliquée avec succès dans des contextes méditerranéens, notamment en Italie (Smiraglia et al., 2019), Espagne (Lavado Contador et al., 2009), Roumanie (Prăvălie et al., 2020), Turquie (Budak et al., 2018 ; Uzuner et Dengiz, 2020) et dans des pays africains méditerranéens comme l'Égypte (Bakr et al., 2012), l'Algérie (Boudjemline & Semar, 2018), la Tunisie (Chandoul et al., 2014) et le Maroc (Ait Lamqadem et al., 2018).

Cet article vise à analyser, cartographier et identifier les zones sensibles à la dégradation dans le bassin versant de l'Oued Laabid à l'aide du modèle MEDALUS, en s'appuyant sur quatre indicateurs principaux : sol, climat, végétation et gestion des terres.

Présentation de la Zone d'Étude

Le bassin versant de l'Oued El Abid, situé en amont du barrage de Bin El Ouidane, appartient au grand bassin versant de l'Oum Er Rbia (Figure. 1-B). Localisé dans le Haut Atlas central, au cœur du Maroc, il s'étend entre les latitudes nord 31°43' et 32°36' et les longitudes ouest 5°13'39» et 6°33'. Ce bassin est principalement drainé par deux cours d'eau majeurs, l'Oued El Abid et l'Assif Ahançal, qui convergent vers le lac artificiel de Bin El Ouidane, avant de rejoindre l'Oued Oum Er Rbia. Administrativement, cette région est partagée entre les provinces d'Azilal et de Béni-Mellal. La zone d'étude se distingue par une topographie accidentée et variée, composée principalement de montagnes, de crêtes, de hauts plateaux, de dépressions et de vallées. Les altitudes prédominantes se situent entre 1500 m et 2500 m, représentant 62,9 % de la superficie totale, confirmant le caractère fortement montagneux du bassin versant (Figure.

1-C). Le climat méditerranéen de la région est marqué par une saison pluvieuse, de novembre à avril, et une saison sèche, de mai à octobre. La couverture végétale est dominée par des chênes verts et des genévriers, accompagnés d'autres espèces et formations forestières, dont la répartition dépend des altitudes et des conditions climatiques (Figure. 1-D).

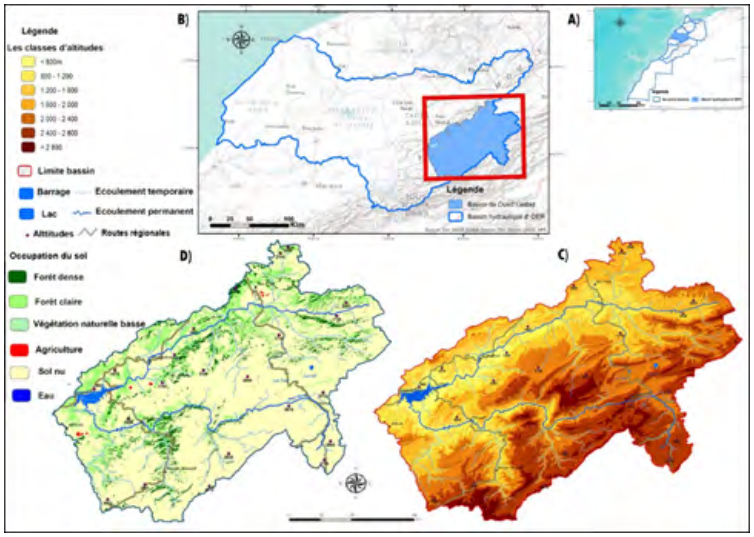

Figure 1. Situation géographique de la zone d'étude
(A) : Localisation de bassin versant Oum Er Rabia, (B) : Situation géographique du bassin versant l'amont du Barrage Bin El Ouidane, (C) : Carte hypsométrique du bassin versant, (D) : Occupation du sol du bassin versant.

Methodologie

La réponse d'un bassin versant aux processus de dégradation des sols dépend de ses caractéristiques géophysiques et anthropiques. L'érosion hydrique constitue un facteur clé de la désertification, influencée par des éléments comme l'érosivité des précipitations, l'érodabilité du substrat et les agents limitant l'érosion. Une analyse approfondie de ces facteurs est essentielle pour évaluer la dynamique érosive et la dégradation des terres. Dans le bassin versant de l'oued El Abid, la préservation des ressources naturelles (sol, eau et végétation) nécessite des aménagements spécifiques pour limiter l'impact de la désertification, un phénomène qui pourrait s'étendre aux sous-bassins de l'oued Oum Er-Rbia, dépendant du climat et des activités humaines.

Pour délimiter les zones sensibles à la dégradation des sols, l'approche ESA (projet MEDALUS) est utilisée. Ce modèle, conçu pour évaluer la sensibilité à la désertification dans la région méditerranéenne, intègre quatre indices principaux : qualité du climat (IQC), du sol (IQS), de la végétation (IQV) et des systèmes d'aménagement (IQSA), ce dernier reflétant l'impact des activités humaines (Kosmas et al., 1999). La combinaison géométrique de ces indices produit un Indice de Sensibilité à la Désertification (ISD) permettant de cartographier les zones sensibles.

Les données spatiales s'effectuent à l'aide des SIG, en utilisant des informations issues de plusieurs tableaux (Table. 1, 2, 3 et 4). Cette approche fournit une base solide pour comprendre et lutter contre la désertification. L'ISD est calculé comme la moyenne géométrique des quatre indices:

$$ISD = (IQC \times IQS \times IQV \times IQSA)^{1/4}$$

1. Indice de Qualité du Climat (IQC)

IQC évalue les conditions climatiques influençant la dégradation des sols. Il est obtenu à partir des précipitations moyennes annuelles (PP), de l'indice d'aridité (IA) et de l'exposition (OR), selon la formule : $IQC = (PP \times IA \times OR)^{1/3}$

Indicateur	Paramètre	Classe	Description	Score
IQC	Précipitations (mm)	1	<300	2
		2	480 - 537	1,8
		3	537 - 600	1,5
		4	>600	1
	Indices d'aridité	1	< 50	1
		2	50 à 100	1,15
		3	100 à 150	1.6
		4	> 150	2
	Aspect	1	N, NE, NW, FLAT	1
		2	S, SE, SW, E	2

Table 1. Classes, description et indices de pondération attribués pour les paramètres utilisés pour la définition de l'indice de qualité du climat (IQC).

2. Indice de Qualité des Sols (IQS)

IQS reflète la vulnérabilité des sols à la dégradation, en tenant compte du matériau parental (**MP**), de la texture (**T**), de la profondeur des sols (**P**) et des pentes (**Pe**) :

$$IQS = (MP \times Pe \times P \times T)^{1/4}$$

Indicateur	Paramètre	Classe	Description	Score
IQS	Indice du Matériau Parental	Matériaux cohérents	Calcaire, Calcaire marneux, Conglomérats dolomie, Conglomérat poudingues, Calcaire lacustre, Grès	1
		Moyennement cohérents	Calcaire marneux, Grès friable	1,5
		Matériel Tendre	Alluvions moyennes grossier, Argile rose	2
	Texture	Texture très Fine	Argile et Limons	2
		Texture Fine	Sable, Argile et Limons	1,5
		Texture Équi-librée	Limons	1
	Indice de profondeur des sols (P)	Très profonds	>40cm	1
		Profonds	Entre 40 et 20 cm	1,5
		Peu profonds /Squelettiques	<20	2
	Pente	Faible	<5%	1
		Moyenne	Entre 5% et 15%	1,33
		Forte	15% et 25%	1,66
		Très forte	>25%	2

Table 2. Paramètres utilisés pour la définition de l'indice de qualité des sols (IQS).

3. Indice de Qualité de la Végétation (IQV)

IQV mesure la résilience du couvert végétal face à la dégradation. Il est calculé à partir de quatre paramètres : protection contre l'érosion (**PE**), résistance à la sécheresse (**RS**), risque d'incendie (**RI**) et couverture végétale (**CV**).

$$IQS = (MP \times Pe \times P \times T)^{1/4}$$

4. Indice de Qualité du Système d'Aménagement (IQSA)

L'IQSA évalue les pressions anthropiques à travers six paramètres : intensité des usages agricoles, infrastructures, urbanisation, gestion de l'eau, déforestation, et érosion. Les données proviennent des bases statistiques nationales et de relevés SIG.

$$IQV = (RI \times PE \times RS \times CV)^{1/4}$$

Indicateur	Paramètre	Classe	Description	Score
IQV	Couverture végétale	1	Élevée	1
		2	Moyenne	1,33
		3	Faible	1,66
		4	Très faible	2
	Risque d'incendie (RI)	Faible	Sols nus, cultures pluriannuelles, cultures annuelles Acacia saharienne Reboisements Feuillus Cèdre, Cèdre Mélangées	1
		Modéré	Mélange de végétation méditerranéenne, Pins, Pins Mélangées, Autres Feuillus Mélangées	1,33
		Élevée	Thuya, Thuya Mélangée, Genévriers, Genévriers Mélangées	1,66
		Très élevée	Forêt du Chêne Vert, Chêne Vert Mélangées	2
	Protection contre l'érosion par la végétation (PE)	Très élevée	Forêts de pins, Pins Mélangées thuya Thuya Mélangée Genévriers	1
		Élevée	Forêt du Chêne Vert, Chêne Vert Mélangées, Cèdre, Cèdre Mélangées	1,33
		Modérée	Végétation méditerranéenne mixte	1,66
		Faible	Sols nus, cultures pluriannuelles, cultures annuelles	2
		Très élevée	Forêts de pins, Pins Mélangées thuya Thuya Mélangée Genévriers	1
	Résistance à la sécheresse (RS)	Élevée	Forêt du Chêne Vert, Chêne Vert Mélangées, Cèdre, Cèdre Mélangées	1,33
		Modérée	Mélange de végétation méditerranéenne	1,66
		Faible	Sols nus, cultures pluriannuelles, cultures annuelles Acacia saharienne	2

Table 3. Paramètres utilisés pour la définition de l'indice de qualité de végétation (IQV).

Indicateur	Paramètre	Classe	Description	Score
IQSA	IUTP	4	Très élevé > 2/ha	2
		3	Élevé 1 - 2/ha	1,66
		2	Modéré 0,5 - 1/ha	1,33
		1	Faible < 0,5/ha	1
	IUTA	4	Très élevé / agriculture intensive	2
		3	Élevé / semi-intensive	1,6
		2	Modéré / agriculture Extensive	1,33
		1	Faible / non agricole	1
	DP	4	Très élevé (Habitants/km²)	2
		3	Élevé (Habitants/km²)	1,66
		2	Modéré (Habitants/km²)	1,33
		1	Faible (Habitants/km²)	1

Table 4. Paramètres utilisés pour la définition de l'indice de qualité Indice de qualité de système d'aménagement (IQSA).

Resultats

La présente étude a permis d'évaluer la vulnérabilité à la dégradation des terres dans la zone étudiée en se basant sur l'approche MEDALUS. Cette méthodologie intègre quatre indices principaux : la qualité du climat, des sols, de la végétation et du système d'aménagement. L'analyse spatiale de ces indices a permis de mieux comprendre la distribution des zones sensibles et de mettre en évidence les facteurs les plus déterminants dans les processus de dégradation. En ce qui concerne l'indice de qualité du climat (IQC), les résultats montrent une prédominance de zones de faible qualité (44,82 %), suivies par des zones de qualité moyenne (39,86 %). Seules 15,30 % de la superficie totale bénéficient d'un climat favorable (Figure 2). Ces données traduisent des conditions globalement défavorables, notamment en raison de la faible pluviométrie et d'un indice d'aridité

caractéristiques d'un climat limitant pour la préservation des terres.

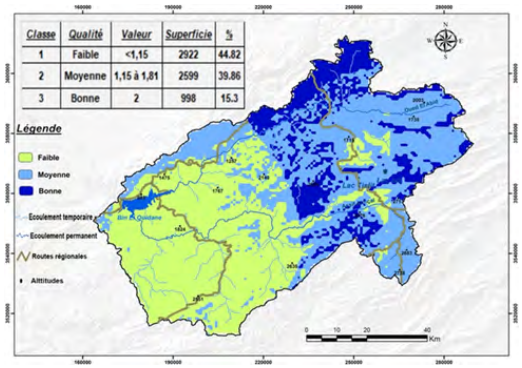

Figure 2. Distribution spatiale de la qualité du climat

Pour l'indice de qualité de la végétation (IQV), les zones de très faible qualité dominent largement, couvrant 62,62 % de la superficie. Ces zones correspondent principalement à des terres nues ou à une couverture végétale insuffisante, aggravée par la vulnérabilité des forêts de chênes verts aux incendies. La végétation de qualité moyenne représente 29,98 %, tandis que seulement 3,09 % des terres affichent une végétation de bonne qualité, mettant en évidence une pression importante sur cet élément clé de la résilience environnementale (Figure 3)

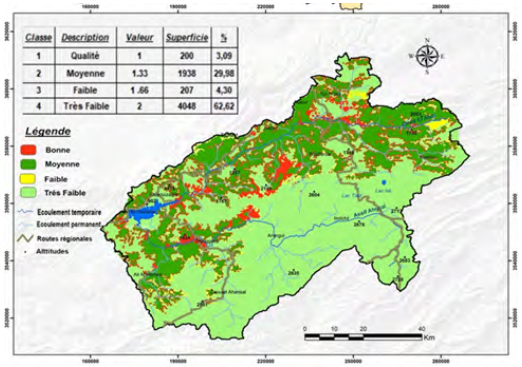

Figure 3. Distribution spatiale de la qualité de végétation

En ce qui concerne la qualité des sols (IQS), l'étude révèle que 58,41 % des terres présentent une qualité moyenne, caractérisée par une profondeur et une texture modérée, mais aussi par une vulnérabilité accrue dans les zones situées sur des pentes ou à proximité des cours d'eau. Les sols de qualité élevée occupent 30,11 % de la superficie, tandis que 11,48 % des terres sont caractérisées par une faible qualité, soulignant des zones particulièrement exposées à la dégradation (Figure 4).

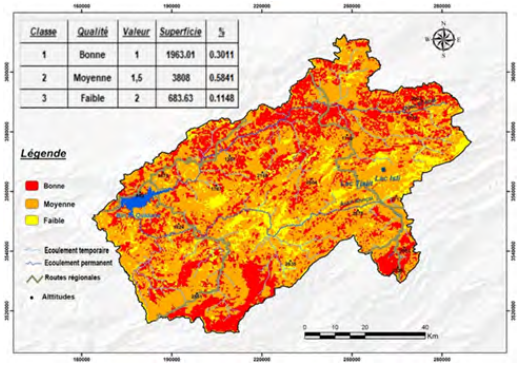

Figure 4. Distribution spatiale de la qualité des sols

Enfin, l'indice de qualité du système d'aménagement (IQSA) met en évidence que 36,15 % de la zone bénéficie d'une gestion modérée, alors que 22,73 % des terres affichent une qualité élevée. Toutefois, les zones à faible qualité d'aménagement restent préoccupantes en raison de la pression anthropique et de l'intensité de l'utilisation des terres agricoles et de parcours (Figure 5).

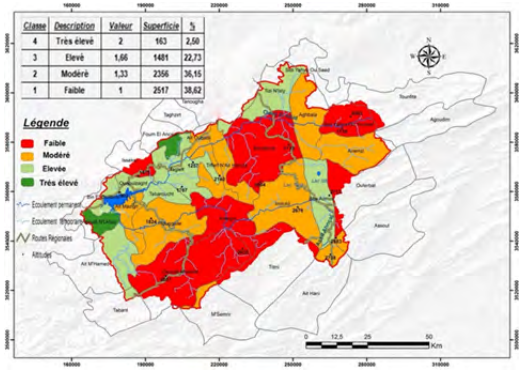

Figure 5. Distribution spatiale de la qualité système d'aménagement

L'indice final de sensibilité à la dégradation (ISD) montre que 44,48 % de la zone étudiée se situent dans la classe « fragile », et 38,19 % sont classées comme « zones potentiellement sensibles ». Ainsi, plus de 60 % du territoire est classé comme « critique à fragile », soulignant l'urgence d'interventions spécifiques pour limiter la dégradation des terres et protéger les ressources naturelles de la région (Figure 6, Table 5).

TYPE	ISD	SUPERFICIE	%
Zones Critiques	<1,3	962	14,75
Zones Fragiles	1,3 - 1,4	2900	44,48
Zones Potentiellement sensibles	1,4 - 1,5	2490	38,19
Zones peu sensibles	>1,5	167	2,5

Table 5. Superficie des quatre classes de sensibilité à la dégradation (ISD).

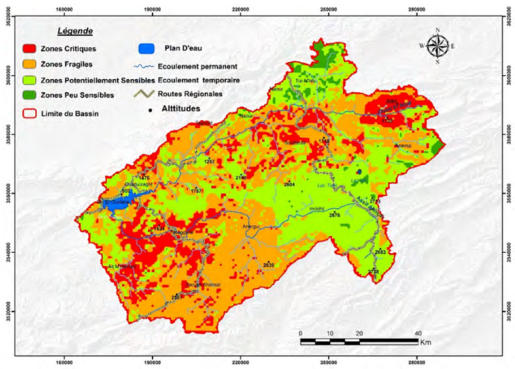

Figure 6. Carte de sensibilité à la dégradation selon l'approche MEDALUS

Conclusion et Discussion

La méthodologie MEDALUS a été appliquée pour la première fois à des zones méditerranéennes sensibles à la dégradation des sols, évoluant ensuite pour inclure des contextes méditerranéens et non méditerranéens. Initialement confrontée à des limites liées à l'intégration des facteurs anthropiques, cette approche a progressivement intégré des adaptations en fonction des données disponibles. Dans le bassin versant d'Oued Laabid, l'application de la méthodologie MEDALUS a permis de cartographier la sensibilité à la dégradation des sols. Les résultats indiquent que 59 % du bassin, principalement les plateaux et dépressions, sont dans des états fragiles à critiques, tandis que les zones montagneuses couvrant 40 % du bassin sont peu à potentiellement sensibles. Les facteurs climatiques, notamment l'augmentation des températures et la sécheresse (confirmée par un SPI atteignant 70 % entre 1984 et 2018), apparaissent comme les principaux moteurs de dégradation. Ces changements induisent une diminution du couvert végétal, augmentant ainsi l'érosion et la salinisation des sols.

L'action anthropique contribue également de manière significative, par le surpâturage, le déboisement, et l'exploitation excessive des terres, aggravant la dégradation des sols. Ces pressions,

exacerbées par la croissance démographique et des pratiques socio-économiques inadaptées, réduisent la matière organique des sols, perturbent leur équilibre hydrique et augmentent leur vulnérabilité à l'érosion hydrique. En conclusion, la conjugaison des pressions climatiques et anthropiques dans le bassin d'Oued Laabid met en évidence la nécessité d'adopter des stratégies de gestion durable pour préserver les ressources naturelles et atténuer les impacts de la dégradation des sols.

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Nova cartografia de solos à escala 1:100 000 para Portugal Continental

A New Soil Cartography at 1:100,000 scale for mainland Portugal

Gonçalo Batista
Mariana Conceição
Ricardo Garcia
Sérgio Oliveira
André Trindade
Cláudia Viana
Jorge Rocha

Resumo

A informação disponível sobre a classificação e cartografia dos solos em Portugal continua insuficiente, dispersa e heterogénea. Persistem lacunas na qualidade, atualidade e uniformidade dos dados, comprometendo a gestão ambiental e o ordenamento do território. As várias fontes apresentam sobreposições, metodologias distintas e deficiências de caracterização e classificação. A atual Carta Geral dos Solos (escala 1:1 000 000) revela-se desatualizada e pouco adequada às necessidades atuais. É assim, fundamental articular, uniformizar, atualizar e disponibilizar toda a informação cartográfica existente para o país, assegurando maior precisão, coerência e utilidade para a gestão integrada e sustentável do território nacional e europeu.

Palavras-chave: Solos; WRB, Cartografia, Compatibilização; Normalização.

Gonçalo Batista
Mariana Conceição
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Ricardo Garcia
Sérgio Oliveira
Cláudia Viana
Jorge Rocha
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Lisbon, Portugal
Associate Laboratory TERRA, University of Lisbon, Portugal

Abstract

The information available on soil classification and mapping in Portugal remains insufficient, scattered, and heterogeneous. Gaps persist in data quality, timeliness, and consistency, undermining environmental management and land-use planning. The various sources show overlaps, differing methodologies, and deficiencies in characterization and classification. The current General Soil Map (scale 1:1,000,000) is outdated and poorly suited to present needs. It is therefore essential to coordinate, standardize, update, and make all existing cartographic information available for the country, ensuring greater accuracy, coherence, and usefulness for the integrated and sustainable management of national and European territory.

Keywords: Soils; WRB; Mapping; Harmonization; Standardization.

André Trindade
Gabinete de Planeamento, Políticas e Administração Geral, Divisão de Análise Estratégica e Monitorização; Centro Interdisciplinar de Ciências Sociais (CICS.NOVA - NOVA FCSH), Lisboa, Portugal

0009-0009-8689-2137
0009-0002-1475-7437
0000-0002-1036-6271
0000-0003-0883-8564
0000-0003-4581-0958
0000-0001-6858-4522
0000-0002-7228-6330

Introduction

Portugal lacks comprehensive cartographic soil information coverage at a scale suitable for environmental management needs. Although various data sources exist (in addition to the numerous published soil maps), they are often inconsistent and insufficient to provide the general and rigorous information necessary to address, in a holistic manner, the challenges associated with soil governance within the framework of environmental policies. Furthermore, efforts to structure foundational information for the creation of new cartography based on previous maps and existing information repositories have also been reported.

The available cartographic information on soils (distribution and characterization) in Portugal has been produced by various institutions and covers the entirety of the mainland territory, presenting some overlaps. This information is scattered across several organizations and is heterogeneous regarding scale, methodologies (field and analytical) employed, information density, classification systems used, and cartographic publication formats, many of which are the result of analog-to-digital conversion. Additionally, it exhibits deficiencies or gaps in characterization and classification (partly stemming from the continuous evolution of knowledge about soil resources and approaches to their study) that need to be addressed.

Despite the acquisition of new data and knowledge, the current General Soil Map of Portugal at a scale of 1:1,000,000 – the sole tool supporting awareness-raising initiatives, spatial planning, thematic cartography at a national level, and the provision of more and better data for cartographic synthesis at the European Union and global scales – remains inadequate. This inadequacy stands in contrast to the situation regarding other foundational thematic cartographies that are relevant for integrated territorial management.

Thus, it is imperative to coordinate, standardize, and make the existing soil cartographic information of the country accessible, enhancing its quality and utility for various applications.

Data

The Soil Map of Portugal (*Carta dos Solos de Portugal*), at a 1:1,000,000 scale, published in 1971, employs a classification system that has not undergone the necessary updates and is now significantly outdated. Therefore, updating the map is essential, utilizing a universal classification system that meets current and future needs.

This article describes the work carried out to correct, harmonize, and validate soil cartography in Portugal at a 1:100,000 scale (covering the regions of Trás-os-Montes and Alto Douro, Entre Douro e Minho, and the Central Interior Zone) and at a 1:25,000 scale (mapping of Soil Series from the former SROA/CNROA, known as the Complementary Soil Maps). The latter includes regions south of the Tejo River, as well as parts of the Central Region and, to a lesser extent, the Northern Region. Due to numerous challenges in gathering information and/or the quality of the existing data, the harmonization process for the cartography at these two scales has been conducted in parallel, depending on the availability of data.

Methods

The operationalization of the aforementioned objectives necessarily requires the convergence of synergies and the involvement and participation of various institutions responsible for soil cartographic information, as well as others engaged in studies of diverse nature related to soil characterization. To this end, it is essential to ensure the organization and coordination of a broad and robust group of specialists with diverse and complementary expertise.

It is also crucial to include various entities (public or private) with a direct interest, at different scales, in the use of soil resource information.

Definition of the cartographic base

The organization of the aforementioned General Soil Map requires, from the outset, consideration of the various geological units (with the support of specialists with knowledge and sensitivity regarding the relationships between lithological differentiation and soil formation) and landforms, in order to globally segregate the different "homogeneous" morphological or physiographic units (in terms of lithology and relief). This necessarily requires support from the Digital Terrain Model (DTM) – as was, in fact, the methodology followed in some soil mapping programs developed in the North and Center of the country. Such differentiation is crucial to optimize the delimitation of soil cartographic units and their alignment with the two key factors in differentiating soil characteristics and their distribution in Mediterranean regions.

The General Soil Map should be based on a prior synthesis of relief and geological units, suggesting the use of the geological map at a scale of 1:500,000 (or larger when available and justifiable), the DTM, the Land Use Map (COS), the Landscape Unit Maps, and maps derived from indicators obtained from relevant thematic cartographic information as a diagnostic basis.

Reorganization and update of information

The organization of the General Soil Map must necessarily account for the diversity of information associated with scale, methodologies, density and quality of data, classification systems, and the publication format of previously produced cartographic documents. Therefore, two main areas of the mainland territory are schematically considered from the outset, to be addressed with differentiated approaches as explained below.

The regions of Trás-os-Montes e Alto Douro, Entre Douro e Minho, and Interior Centro

The reorganization and synthesis of the cartography for these regions are relatively facilitated by the fact that the existing soil cartography (at a scale of 1:100,000) was developed within the conceptual framework of land units, through the prior delineation of physiographic units that are homogeneous in terms of climate, geology, and relief. Furthermore, this cartography contains dense information regarding the morphological description of soil units and their basic analytical characterization, employing internationally standardized methodologies and globally recognized classification systems. Finally, the information from the reference soil profiles generally includes their respective locations and the specification of the parameters essential for their environmental contextualization.

However, the maps for these regions were published in different formats, and their legends exhibit some variation, ranging from the FAO Legend (1974) to the Revised FAO Legend (1988) and the WRB (1998 version). Therefore, to eliminate potential discrepancies and ensure uniformity of information, it is essential to:

(i) First, proceed with the analog-to-digital conversion of the available thematic base cartography used to develop the Soil Map of Trás-os-Montes e Alto Douro and evaluate the internal consistency of the soil cartographic units with the homogeneous physiographic units;

(ii) Harmonize the delineation of homogeneous physiographic units and adjacent soil cartographic units at the boundaries between each pair of these regions;

(iii) Address the inconsistencies between the legends of the mentioned maps by creating equivalence tables and integrating them into an information transformation system for the WRB (2006 or 2014 version, or a more recent one), while ensuring compatibility with the Harmonized World Soil Database (HWSD) being developed by the International Network of Soil Information (INSII).

The regions of Algarve, Alentejo and Litoral Centro

In these regions, the existing cartography in georeferenced vector and raster formats was developed at a scale of 1:25,000 (the so-called Series Maps), which served as the basis for its publication on paper at a scale of 1:50,000. Its integration into the General Soil Map of Portugal (CGSP) is significantly more complex than in the previous case, as the cartography was not structured based on information obtained from a prior differentiation of basic or homogeneous physiographic units. As a result, the respective cartographic units are not sufficiently systematized according to the dominant factors of soil formation. This is further complicated by the fact that information on geological units was only sufficiently detailed at a later stage (Monteiro, 2004).

Additionally, the soil classification system used (Portuguese Soil Classification) has not undergone the necessary updates and alignment with global classification systems. At the same time, the methodological standardization system (field and laboratory) has gradually been diluted, leading to an increased number of soil units (included in the cartographic documents) that are either incompletely characterized or lack any characterization at all. Indeed, the information in the respective descriptive reports is sparse (incomplete), and many soil units were classified inconsistently, particularly those in the areas of the Central Coastal Zone, which are based exclusively on sedimentary rocks.

Conclusion

The update of the General Soil Map of Portugal (Carta Geral dos Solos de Portugal, CGSP) represents a significant opportunity to unify the classification (and communication) system and the various methodologies, organize information and general and thematic databases, address and mitigate characterization deficiencies, promote the improvement and reorganization of existing cartography, encourage the use of new technologies, and adapt information to better support land-use planning, soil degradation prevention, and the management and conservation of natural resources.

These are essential conditions for knowledge transfer, legislative support, integration of soil protection into other environmental and resource conservation policies, and for stimulating and guiding research. This initiative aims to foster the development of soil science by addressing identified gaps, priorities, and synergies, improving interactions between the scientific community involved in fundamental and applied I&D activities on soils and the end-user communities and stakeholders. Ultimately, it seeks to enhance impact through the adaptation and dissemination of developed knowledge and technologies.

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Delimitação de distritos de solos em Portugal Continental

Delimitation of Soil Districts in mainland Portugal

Mariana Conceição
Gonçalo Batista
Ricardo Garcia
Sérgio Oliveira
André Trindade
Cláudia Viana
Jorge Rocha

Resumo

A Diretiva de Monitorização do Solo da UE promove a gestão sustentável do solo nos Estados-Membros, propondo Unidades de Solo (US) dentro de Distritos de Solo para monitorização/governação eficazes. A heterogeneidade do solo é abordada com técnicas avançadas, incluindo machine learning, geoestatística e SIG. A metodologia avalia a qualidade do solo utilizando dados climatológicos, do uso/tipo do solo e propriedades do solo, para delinear US. A harmonização dos sistemas de monitorização e a criação de um observatório do solo aumentam a fiabilidade dos dados. O projeto nacional, financiado pela FCT, destaca o envolvimento das partes interessadas e a sustentabilidade agrícola.

Palavras-chave: Distritos de Solo; Unidades de Solo; Modelação; SIG.

Mariana Conceição
Gonçalo Batista
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Ricardo Garcia
Sérgio Oliveira
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Associate Laboratory TERRA, University of Lisbon, Portugal
André Trindade
Gabinete de Planeamento, Políticas e Administração Geral, Divisão de Análise Estratégica e Monitorização, Centro Interdisciplinar de Ciências Sociais (CICS.NOVA - NOVA FCSH), Lisboa, Portugal

Abstract

The EU Soil Monitoring Directive promotes sustainable soil management in Member States, proposing Soil Units (SU) within designated Soil Districts for effective monitoring and governance. Addressing soil and land-use heterogeneity requires advanced statistical techniques, including machine learning, geostatistics, and GIS. The methodology assesses soil quality using climatological, land-use, soil properties, and lithological data to map multi-purpose SU. Harmonising monitoring systems nationally and creating a comprehensive soil observatory improve data reliability and decision-making. The national soil monitoring project, funded by FCT, emphasises stakeholder engagement through workshops, participatory planning, and training to support sustainable soil management and agriculture sustainability within the EU.

Keywords: Soil Districts; Soil Units; Modeling; GIS.

Cláudia Viana
Jorge Rocha
Centre of Geographical Studies, Institute of Geography and Spatial Planning, University of Lisbon, Portugal
Associate Laboratory TERRA, University of Lisbon, Portugal

0009-0002-1475-7437
0009-0009-8689-2137
0000-0002-1036-6271
0000-0003-0883-8564
0000-0003-4581-0958
0000-0001-6858-4522
0000-0002-7228-6330

Introduction

The European Union (EU) Soil Monitoring Directive is a key legislative instrument designed to promote sustainable soil management practices in the member states. The directive outlines the establishment of Soil Units (SU) within designated Soil Districts, which are fundamental for soil monitoring and governance. The parameters used are the responsibility of each Member State, although the need to reach a consensus that encompasses at least a few basic parameters is emphasized.

However, the heterogeneous nature of soil typology (WRB 2014) and land use across the member states presents significant challenges in effectively delineating these units. Addressing this complexity requires sophisticated methodologies and interdisciplinary collaboration.

Recent advancements in statistical techniques and modeling have provided new opportunities for the precise delineation of SU. Machine learning (ML) algorithms, geostatistical analyses, and geographic information systems (GIS) have emerged as valuable tools in this context. Various numerical approaches, including fuzzy clustering and principal component analysis (PCA), have been proposed to delineate SU, leveraging various environmental and soil data sources.

However, achieving multi-use SU remains challenging due to the intricate interactions between soil properties. A dynamic methodology that integrates soil quality assessment is proposed in response to these challenges. A central aspect of the proposed methodology is using ML algorithms and integrating diverse datasets. The primary inputs include climatic data (e.g., maximum and minimum precipitation and maximum and minimum temperature), land use maps, soil element data (e.g., organic carbon, phosphorus, zinc, magnesium, among others), and lithological information. Tasks focused on lithological mapping, climate response units, and soil unit clustering are integral components of the proposed framework, aiming to develop a robust methodology for SU delineation.

The future harmonisation of monitoring systems at the national level is emphasised, along with the establishment of a comprehensive soil observatory. With the creation of a national soil observatory, it will be possible to hold all the important information on soils in one place, making it easier to share, use and add new information. These initiatives enhance data reliability and facilitate soil health assessment, contributing to evidence-based decision-making. Moreover, the project highlights the importance of stakeholder participation and collaboration, especially among rural development agents.

The project aims to support evidence-based decision-making at the agricultural exploitation level and inform rural development policies by creating an information system to record the results of soil analysis and cultural practices. Ultimately, the national soil monitoring system project (MLSOIL) seeks to advance sustainable soil management practices through interdisciplinary collaboration and innovative methodologies tailored to the diverse contexts within the EU. The EU aims to safeguard soil resources for future generations through concerted efforts while promoting agricultural sustainability and rural development.

Recent Developments in Soil Units

The European Union Soil Monitoring Directive (Direção-Geral do Ambiente, 2023) provides for the definition of soil districts (administrative units) and associated soil units (monitoring units with a minimum level of harmonisation, SU) as areas for soil monitoring and the implementation of sustainable soil management. Adopting distinct soil nomenclature at the national level, combined with a wide diversity of land cover and land use, makes it very difficult to establish and define these boundaries. It is important to emphasise that these soil units should constitute the basic units of governance for soil management and adopt

measures to meet the requirements in the proposed directive, especially regarding soil health monitoring and assessment.

The uniformity of soil properties within the SU is crucial for sustainable soil management, long-term productivity, and the prevention of environmental issues. Studying spatial variation in soil fertility status is essential for sustainable activities (Taghizadeh-Mehrjardi et al., 2020). In recent decades, considerable advancements in statistical techniques and modelling approaches have allowed for the precise delineation of agricultural zones using new methods such as ML, geographic information systems (GIS), remote sensing, and geostatistics. Several numerical approaches have been proposed for SU delineation based on soil properties, including fuzzy k-means cluster analysis (Zeraatpisheh et al., 2020), fuzzy c-means clustering algorithm, and PCA. However, selecting the appropriate technique/approach depends on the purposes for which the SU are being delineated. Previous studies have documented the application of SU delineation for agricultural systems, using various environmental and soil data sources, such as pedo-geomorphological factors, soil nutrients, and intrinsic soil properties (e.g., electrical conductivity, pH, particle size distribution, soil organic matter, nitrogen, phosphorus, and potassium) (Zeraatpisheh et al., 2020).

The main reason for developing SU is to delineate homogeneous areasHowever, some statistical tests commonly used to determine SUs, such as one-way analysis of variance, only consider individual soil properties. Kerry et al. (2021) investigated whether the SU identified using remote sensing, topographic, and yield data were optimal for managing multiple nutrients or soil properties simultaneously and found that although the units could be used to manage more than one property, they were not truly multi-use and could not be used to manage all or most properties at once.

Therefore, a dynamic delineation methodology is needed to assess the interactions of soil and multiple properties in combination. Soil quality assessment can be considered effective in representing the quality and sustainability of ecosystems. It considers the interaction of different variables (e.g., soil properties) and is based on other references and thresholds to classify the soil into various soil quality levels. Soil quality assessment could be used to evaluate the homogeneity of the delineated SUs.

Regarding the homogeneity of the SUs within soil districts, the first version of the Soil Monitoring Directive (Direção-Geral do Ambiente, 2023) suggests the use of the geostatistical Bethel algorithm to deal with (few) soil properties, retrieved from Copernicus platform, and ensure interactions of soil properties with a variation coefficient of less than 5% within each SU.

Methodology

Soil districts should constitute the basic units of soil management and decision-making to comply with the requirements in this Directive, especially regarding soil health monitoring and assessment. The number, geographic extent, and boundaries of the soil districts for each Member State should be determined to facilitate the implementation of the EU Regulation. The minimum number of soil districts for each Member State should correspond to the number of NUTS I territorial units. Member States must designate a competent authority for each soil district to ensure proper soil governance.

All actions will be carried out in close coordination with the European Commission (EC), the Joint Research Centre (JRC), the Portuguese Soil Partnership (PPS), and, in some cases, with farmers and foresters – citizen science. An important feature of these tasks is related to concepts. Soil quality can transform soil science from a neutral science in terms of value into a value system, and soil quality can even be referred to as promoting ideas of politically correct soil. Furthermore, there are also different definitions and, consequently, different understandings of structural concepts such as Soil Quality, Soil Health, Ecosystem Services (of the Soil), or Soil Functions that need to be addressed

(Weninger et al., 2024).

When establishing the geographic extent of the homogeneous soil unit grid, Member States may take into account existing administrative units and should aim for homogeneity within each soil district about the following parameters: i) soil type as defined in the World Reference Base for Soil Resources; ii) climatic conditions; iii) environmental zone as described in the Alterra Report; and iv) land use or land cover as used in the Land Use/Cover Area frame Statistical Survey (LUCAS) (or similar).

Regarding i), we will provide a 1:100,000 lithological map for mainland Portugal. We also can access better climatic data (ii) than the suggested WorldClim dataset. These data have a spatial resolution of 1 km² and correspond to a somewhat outdated climatological normal. We will use the 1982-2010 climatological normal from the Portuguese Institute for Sea and Atmosphere (already acquired). Considering that we also have a detailed Official Land Use and Cover Map (1:25,000; Carta de Uso e Ocupação do Solo (COS) 2018) (iv), it will be possible to process more detailed information than those suggested in (iii), both geometrically and/or semantically. Therefore, we will develop Homogeneous Climate Response Units (HCRUs).

This data will allow us to create the geographic grid of soil units, which will be the basis for all modelling processes. The second phase will cover the clustering process of the geographic grid of homogeneous soil units. This will be done using soil property data provided by the EU (e.g., Copernicus), namely phosphorus content, total nitrogen content, granulometric distribution (clay, silt, sand), coarse fragments, pH, organic carbon (OC), carbonate content, extractable potassium content, and cation exchange capacity.

Additionally, there are also data on pollutants. For example, copper (Cu), mercury (Hg), and zinc distribution in surface soils. Cu, for example, is correlated with soil properties (pH, texture, OC), climate, and lithology. Several clustering methods will be applied and evaluated after dealing with this data variability and multicollinearity (Zeraatpisheh et al., 2020). The most positive result of all of the tests carried out so far were those where the parameters used were the NUTS II, the Corine Land Cover, the soil bulk density at a depth of 0 to 10 cm, the copper concentration, the nitrogen content, the organic carbon content, the phosphorus content and the soil pH, which resulted in 14 soil units all over mainland Portugal.

Establishing a harmonised national monitoring system, along with the systematisation and standardisation of indicators for the European Soil Strategy, is also necessary. This contributes to effectively applying, monitoring, and evaluating management measures and soil policies at different levels, from national to regional and local. Thus, several methods will be tested and compared (Lawrence et al., 2020).

Conclusion

To comply with the obligations related to soil health monitoring (for collecting soil samples), the competent authorities in the Member States may need to request landowners to grant them access to their properties following the applicable national rules and procedures. Member States may also require landowners to implement measures to manage the soil sustainably. Data from soil analysis periodically carried out on agricultural plots, in integrated and organic production modes, that benefit from support under the Common Agricultural Policy, could contribute to monitoring the soil health status in the country's agricultural areas, i.e., the soil observatory.

To achieve this, it will be necessary to ensure the reliability and harmonisation of sample collection procedures, analytical methods, and data collection in a national information system. This data, combined with information about cultural practices in each plot (>= 100 m²) which farmers are required to record, would allow for the assessment of the impact of these practices on soil health.

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Recuo de arribas costeiras e suscetibilidade ao perigo na região de Safi, Marrocos

Coastal Cliff Retreat and Hazard Susceptibility in the Safi Region, Morocco

Chaima Imam
Mohamed Chaibi
Fatima El Bchari
Mohamed Ayt Ougougdal
Abdessamad Charif
Halima Ait Malek

Resumo

As falésias costeiras instáveis representam um risco significativo para as infraestruturas e as populações ao longo da costa atlântica marroquina. Este estudo investiga a evolução multidecadal das falésias de Safi (1954–2020) utilizando fotografias aéreas, ferramentas SIG e o modelo Digital Shoreline Analysis System (DSAS) para quantificar as taxas de recuo das falésias. Os resultados revelam um recuo generalizado, variando entre 0,04 e 0,08 m/ano, com os valores mais elevados observados nos setores ricos em argila, suscetíveis a deslizamentos. Os ciclos de precipitação e de saturação agravam essa instabilidade, enquanto a ação marinha desempenha um papel secundário. Estes resultados destacam a necessidade de uma gestão costeira integrada e de uma monitorização contínua para apoiar uma prevenção eficaz dos riscos.

Palavras-chave: Falésias costeiras; Taxas de recuo; Método DSAS; Costa atlântica; Safi; Marrocos.

Abstract

Unstable coastal cliffs represent a major hazard for infrastructure and populations along the Moroccan Atlantic coast. This study investigates the multi-decadal evolution of the Safi cliffs (1954–2020) using aerial photographs, GIS tools, and the Digital Shoreline Analysis System (DSAS) to quantify cliff retreat rates. Results reveal a widespread retreat ranging from 0.04 to 0.08 m/year, with the highest values observed in clay-rich sectors prone to landslides. Rainfall and saturation cycles exacerbate this instability, whereas marine action plays a secondary role. These findings highlight the need for integrated coastal management and continuous monitoring to support effective risk prevention.

Keywords: Coastal cliffs; recession rates; DSAS method; Atlantic coast; Safi; Morocco.

Chaima Imam
Mohamed Chaibi
chaibimohamed@gmail.com
Fatima El Bchari
Mohamed Ayt Ougougdal
Abdessamad Charif
Halima Ait Malek
Department of Earth Sciences, Polydisciplinary Faculty of Safi, Cadi Ayyad University, Marrakech, Morocco

0009-0000-3070-9764
0000-0003-0942-1015
0000-0002-7398-5985

Introduction

Les côtes figurent parmi les environnements les plus dynamiques de la surface terrestre (Mishra et al., 2022). Près d'un quart de la population mondiale et de nombreuses activités économiques sont concentrés dans ces zones littorales (Christopher et Robert, 2003). Cependant, elles sont aujourd'hui confrontées à des perturbations naturelles croissantes et à une dégradation anthropique accrue, notamment l'élévation du niveau de la mer, l'érosion côtière et la surexploitation des ressources (Nassar et al., 2019). L'érosion côtière est particulièrement préoccupante, affectant environ 66 % des côtes mondiales (Luijendijk et al., 2018). Bien que l'attention ait souvent été portée sur l'évolution des plages et des zones humides, les falaises rocheuses, qui représentent 80 % du littoral mondial, ont été relativement peu étudiées (Sunamura, 1992; Stephenson et al., 2013).

Les falaises côtières subissent un recul progressif pouvant menacer les infrastructures situées en haut ou en bas des escarpements, telles que les habitations, les routes et les sites naturels protégés (Prémaillon et al., 2018). Cette prise de conscience a favorisé le développement d'outils de surveillance et de modélisation pour évaluer et anticiper l'évolution du recul des falaises (Zhang, 2011; Nassar et al., 2019). De nombreuses études ont utilisé des cartes historiques et des photographies aériennes pour analyser ce phénomène dans diverses régions (ex.: Californie, Portugal, Royaume-Uni, Italie, Australie, Canada, Inde et France). Cependant, les recherches sur l'évolution des falaises restent quasiment absentes en Afrique, notamment sur le littoral marocain, pourtant caractérisé par certaines des falaises les plus élevées du continent (Weisrock, 1985).

Pour combler ce manque, nous avons étudié l'évolution multidécaire des falaises de la région de Safi, connues pour leurs instabilités naturelles (El Bchari et al., 2019, Ayt Ougougdal et al., 2020). Ces instabilités, particulièrement marquées dans les falaises argileuses, génèrent des risques majeurs (glissements de terrain, effondrements, chutes de blocs) pouvant entraîner des pertes humaines et des dommages matériels. L'objectif de cette étude est de déterminer les taux et modalités de recul afin d'améliorer la compréhension du comportement érosif de cette zone. En utilisant les Systèmes d'Information Géographique (SIG), nous avons quantifié les taux d'érosion, analysé leurs variations spatiales et identifié les principaux facteurs responsables du recul des falaises depuis 1954. Ces données sont essentielles pour aider les décideurs locaux à mieux gérer les risques liés à l'érosion côtière dans la région de Safi.

Présentation de la Zone d'Étude

La zone d'étude s'étend sur la côte atlantique du Maroc, du Cap Beddouza au nord jusqu'aux falaises de Jorf Lihoudi au sud, sur une longueur totale d'environ 48 km (Figure 1). La ville de Safi, située au milieu de cette zone côtière (Figure 1), constitue un important pôle urbain accueillant environ 700 000 habitants. Le littoral se caractérise par une dominance de falaises, dont l'existence est principalement liée à la dynamique marine (Weisrock, 1985).

L'évolution morphologique actuelle de la côte de Safi est étroitement associée à l'héritage quaternaire, à la nature et la structure des paléo-formations ainsi qu'à la néotectonique (Ayt Ougougdal et al., 2020). Historiquement, lors des phases transgressives du Quaternaire récent, l'érosion marine a été particulièrement intense (Weisrock, 1985). Au cours du dernier million d'années, cinq transgressions majeures ont été enregistrées sur l'Atlantique marocain (Gigout, 1951; Michard, 1976; Witam, 1988). Ces séquences transgressives ont fortement impacté les hautes falaises de Safi, où l'élévation du niveau de la mer a favorisé une érosion marine intense, comme observé dans d'autres régions côtières (Soldati et al., 2018).

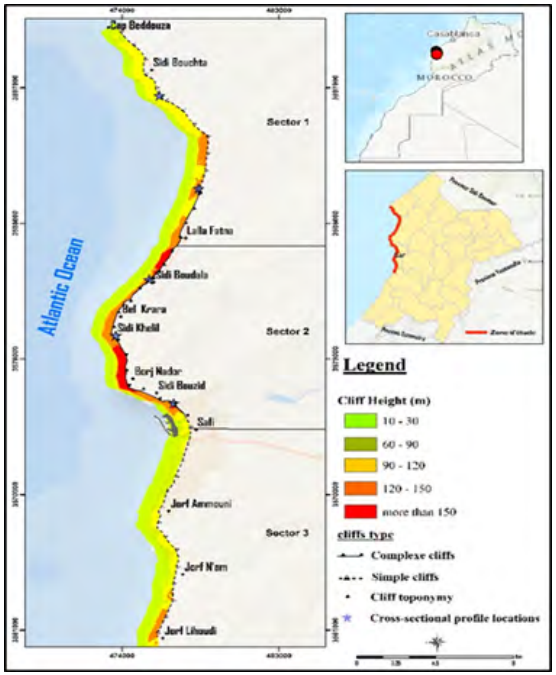

Figure 1. Localisation des falaises côtières étudiées

Methodologie

L'analyse de la dynamique du recul des falaises dans la région de Safi repose sur une approche diachronique utilisant des outils de télédétection et de géomatique. La méthodologie adoptée comprend plusieurs étapes clés allant de la collecte des données à l'analyse des résultats (Figure 2).

Collecte des données

La première phase consiste à rassembler des données géospatiales issues de différentes sources (table 1):

— Photographies aériennes historiques (1954 et 1983) permettant une analyse de l'évolution sur plusieurs décennies.

— Orthophoto récente (2020) servant de référence actuelle pour comparer les changements morphologiques.

Document	Date	Nombre d'images	Échelle	Type d'image	Mission Référence
Photographies aériennes	1954	55	1/10000	Numérique noir et blanc	SHOM
	1983	30	1/17500		ANCFCC
Orthophotographies Aériennes	2020	1	1/5000	Numérique couleur	ANCFCC
Cartes topographiques	2016/2018	13	1/25000	Numérique couleur	ANCFCC

SHOM : Le service hydrographique et océanographique de la Marine
ANCFCC : L'Agence Nationale de la Conservation Foncière, du Cadastre et de la Cartographie
Table 1. Synthèse des documents utilisés pour l'analyse diachronique
Prétraitement des données

Avant toute analyse, les images doivent être préparées afin d'assurer leur compatibilité spatiale et temporelle. Cette étape inclut :

— Le géoréférencement, qui consiste à aligner les images historiques sur une référence cartographique précise (l'orthophoto de 2020), en utilisant des points de contrôle bien identifiés sur le terrain.

— La définition du marqueur de falaise, qui permet de tracer précisément la limite du haut de falaise à chaque date d'analyse.

Création des données spatiales

Une fois les images préparées, la digitalisation des traits de côte est réalisée à l'aide du logiciel ArcGIS 10.8. Trois éléments sont produits:

— Les lignes de falaises pour chaque période analysée (1954, 1983, 2020).

— Les transects perpendiculaires aux falaises, créés via l'outil DSAS (Digital Shoreline Analysis System).

— Les bases de données associées, regroupant les coordonnées spatiales et les paramètres d'érosion.

Calculs et analyses

L'évolution des falaises est ensuite quantifiée à l'aide de DSAS, qui permet d'extraire plusieurs indicateurs.Le taux de recul des falaises exprimé par plusieurs métriques :

— EPR (End Point Rate): vitesse moyenne de recul entre deux dates.

— LRR (Linear Regression Rate): tendance moyenne du recul sur l'ensemble des périodes.

— NSM (Net Shoreline Movement): déplacement total du trait de côte.

— L'estimation de la marge d'erreur en prenant en compte les incertitudes liées aux sources de données et aux méthodes de digitalisation (erreur RMS, précision des points de contrôle, distorsion des images anciennes).

Analyse et interprétation

Les résultats obtenus permettent d'identifier:

— Les variations spatiales du recul des falaises, en mettant en évidence les secteurs les plus vulnérables.

— Les facteurs influençant la dynamique d'érosion, notamment la lithologie, la morphologie des falaises et les conditions marines.

— L'évaluation de la susceptibilité aux risques, en croisant les données d'érosion avec les enjeux humains et les infrastructures situées en bord de falaise.

— Cette méthodologie offre une vision détaillée de l'évolution des falaises de Safi et constitue un outil essentiel pour la gestion des risques côtiers et l'aménagement durable du littoral.

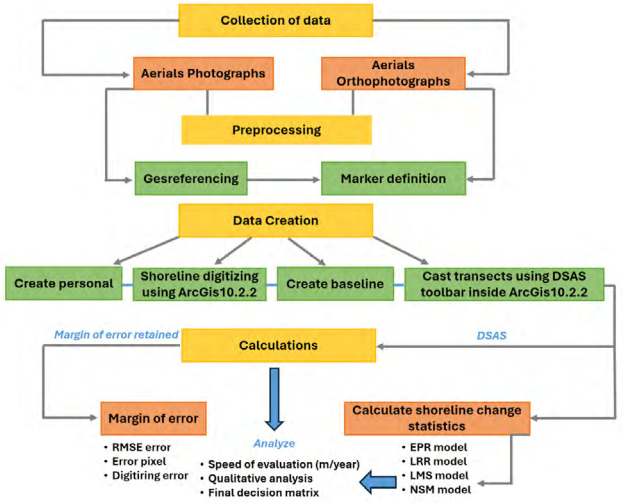

Figure 2. Framework de la méthodologie adoptée

Resultats

Les résultats montrent que sur une période de 66 ans, l'ensemble des secteurs étudiés le long de la côte de Safi est soumis à une dynamique régressive significative. Environ 70,03 % des transects ont présenté des signes d'érosion, avec des taux moyens de recul variant de 0,07 m/an à 0,08 m/an. Le secteur 2 a enregistré les taux de recul les plus élevés, avec un taux moyen de 0,08 m/an, tandis que le secteur 1 a affiché un taux moyen de 0,07 m/an. Le secteur 3, au sud de Safi, a montré les taux les plus bas, avec un taux de 0,04 m/an. Les indices EPR, LRR et LMS ont révélé des résultats similaires, confirmant la fiabilité de ces indicateurs pour expliquer la dynamique régressive des falaises côtières (Figure 3).

Sur la base de l'analyse des documents en termes de qualité et de résolution, il ressort que les marges d'erreur associées à l'identification des différents marqueurs varient entre ±0.009 m et ±0.01 m pour les trois secteurs étudiés, entre 1954 et 2020.

Ces faibles valeurs d'erreur témoignent de la précision du processus d'identification, malgré les variations possibles de la qualité des documents. Il est important de noter que, même avec ces marges d'erreur, l'intégration de l'erreur dans le calcul de la moyenne de retrait ou sa soustraction du taux de recul n'affecte pas la cohérence des résultats, ce qui renforce la robustesse des observations. Ces marges d'erreur sont considérées comme raisonnables et assurent la fiabilité des résultats (Table 2).

Secteur	EPR (Mean) (m/yr)	EPR - Error (m/yr)	EPR + Error (m/yr)
Secteur 1	-0.0716	-0.0616	-0.0816
Secteur 2	-0.0842	-0.0742	-0.0942
Secteur 3	-0.0493	-0.0403	-0.0583

Table 2. Effet de l'Ajout de l'Erreur sur le Taux de Retrait Moyen.

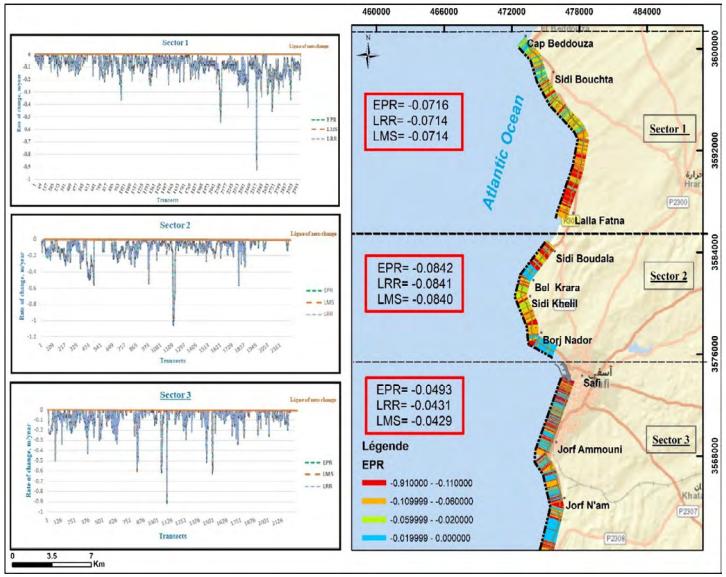

Figure 3. Résultats des vitesses de recul du trait de côte et valeurs de chaque transect pour chaque secteur.

Trois espaces sont distingués comme mentionner avant:

- Un secteur au recul faible 0,04 m/an avec une erreur qui ne dépasse pas 0,009 m le long de secteur 3 au sud de la ville de Safi ver les falaises de Jorf Lihoudi,
- Un secteur à recul modéré 0,07 m/an entre Cap Beddouza et Lalla Fatna au secteur 3 avec une erreur de 0,01 m,
- Un secteur marqué par un recul fort (0,08 m/an) de secteur 2 au milieu de la ligne côtière étudier avec une erreur de 0,01 m.

Cette représentation révèle une variabilité considérable dans la répartition spatiale et également identifiée pour les périodes intermédiaires: entre 1954-1983, les valeurs apparaissent

beaucoup plus élevées pour la période de 1983-2020 à l'exception du secteur 3, qui a atteint un certain équilibre (Table 3).

Vitesse de recul (m/an)	Secteur 1	Secteur 2	Secteur 3
1954-1983	0,083	0,10	0,0495
1983-2020	0,073	0,079	0,0495
1954-2020	0,07	0,08	0,04

Table 3. Évolution de la Vitesse de Recul du trait de côte par Secteur pour différentes périodes.

Discussion

Nos résultats montrent que la récession des falaises dans la région de Safi est relativement modérée par rapport à d'autres formations similaires à l'échelle mondiale. Toutefois, l'aléa de recul des falaises demeure une réalité, avec des taux de récession variant en fonction des conditions géologiques et des forçages environnementaux. En effet, les falaises argileuses étudiées présentent des taux de récession plus faibles que ceux documentés ailleurs, où ils oscillent généralement entre -0,15 et -0,30 m/an (Woodroffe, 2002; Hurst et al., 2016).

L'aléa lié à la récession des falaises est conditionné par une combinaison de facteurs géologiques, climatiques et marins. Les comparaisons avec des sites européens, tels que les falaises du Bessin en France (-0,15 à -0,20 m/an sur 150 ans) ou celles du sud de l'Angleterre (0,22 à 0,32 m/an depuis 1870), montrent que la variabilité des taux de récession est fortement influencée par la nature des matériaux et l'exposition aux conditions océaniques. À Safi, la présence de formations argileuses favorise la sensibilité des falaises à cet aléa, notamment sous l'effet des précipitations et des cycles de saturation/sécheresse, qui facilitent les processus de désagrégation et de glissements (Weisrock, 1985; Ayt Ougougdal et al., 2020).

L'aléa de récession se manifeste également par la diversité des mécanismes de déstabilisation observés. L'action des vagues, bien que présente, est atténuée par la relative résistance des formations rocheuses locales. En revanche, les précipitations intenses et les tempêtes augmentent la fréquence des instabilités, en particulier sur les versants argileux où l'altération des matériaux fragilise les parois et favorise des effondrements par glissements et éboulements (Trenhaile, 2014; Hurst et al., 2016). Ces processus sont souvent amplifiés par la configuration morphologique des falaises, notamment leur hauteur et leur exposition aux vents dominants.

La distribution spatiale des taux de récession le long du littoral de Safi illustre l'hétérogénéité de cet aléa. Les zones où les formations argileuses sont prédominantes enregistrent les taux de récession les plus élevés, tandis que les secteurs composés de calcaires ou de beach-rocks apparaissent plus stables. Cette variabilité est également modulée par des facteurs anthropiques: les aménagements côtiers (digues, urbanisation) modifient les dynamiques naturelles et peuvent, dans certains cas, accentuer localement la récession en perturbant les écoulements et en concentrant les contraintes sur des points vulnérables.

L'aléa de récession des falaises à Safi résulte d'une interaction complexe entre processus naturels et facteurs externes. La variabilité des taux de recul met en évidence l'importance de la composition lithologique et des conditions climatiques dans la dynamique côtière. La prise en compte de ces éléments est essentielle pour une meilleure évaluation des risques et une gestion adaptée du littoral face aux aléas naturels et anthropiques.

Conclusion

L'étude de la récession des falaises dans la région de Safi met en évidence une dynamique côtière influencée par une combinaison complexe de facteurs géologiques, marins et climatiques. Nos résultats montrent que, bien que les taux de récession observés soient modérés par rapport à d'autres formations similaires à l'échelle mondiale, l'aléa reste significatif et spatialement hétérogène. La nature des matériaux joue un rôle clé: les formations argileuses, plus sensibles à l'altération et aux cycles hydrologiques, enregistrent des taux de recul plus élevés que les secteurs calcaires plus résistants.

L'action des vagues, bien que présente, apparaît comme un facteur secondaire par rapport aux effets des précipitations et des variations climatiques, qui contribuent largement aux processus de déstabilisation. Les événements extrêmes, tels que les tempêtes et les précipitations intenses, accélèrent ponctuellement la récession en augmentant la fréquence des glissements et des effondrements. De plus, les aménagements côtiers peuvent localement intensifier cet aléa en modifiant les dynamiques d'érosion et de sédimentation.

Ces observations soulignent l'importance d'une approche intégrée pour évaluer et gérer les risques côtiers. Une surveillance continue des secteurs les plus vulnérables, combinée à des stratégies d'aménagement adaptées, permettrait d'anticiper les évolutions futures et de mieux protéger les infrastructures et les populations exposées. Enfin, la prise en compte des interactions entre les forçages naturels et les pressions anthropiques est essentielle pour affiner les modèles prédictifs et renforcer la résilience du littoral face aux changements environnementaux à venir.

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Análise dos desafios jurídicos, ambientais e socioeconómicos das autoestradas da água em Marrocos: um estudo de caso

Analyse des enjeux juridiques, environnementaux et socio-économiques des autoroutes de l'eau au Maroc : une étude de cas

Samira Idllalène
Moulay Abdessamad Afifi
Alazali Mounia
Mohamed Mouch
Benabderrazik Radia
Lahcen Ouahmane
Abderrafie El Maknissi

Resumo

O projeto "Autoestradas Aquáticas" (RA), é um pilar da política nacional da água em Marrocos. O seu objetivo é transferir o excedente de água entre bacias hidrográficas. A implementação do RA gera desafios de governação substanciais, uma vez que ultrapassa o âmbito de atuação das agências tradicionais de bacias hidrográficas, exigindo, por isso, uma reestruturação institucional e uma atualização legislativa. Para investigar a integração sistémica do RA no quadro jurídico e institucional, o projeto de investigação «AutEauGov», financiado pela Universidade Cadi Ayyad, adota uma abordagem metodológica distintamente multidisciplinar e transversal, integrando o Direito, a Economia, a Geografia e as Ciências Ecológicas.

Palavras-chave: transferência de água, legislação, Marrocos, projecto AuTeauGov.

Samira Idllalène
Moulay Abdessamad Afifi
Alazali Mounia
Mohamed Mouch
m.mouch@uca.ac.ma
Lahcen Ouahmane
Abderrafie El Maknissi
Faculté polydisciplinaire, Université Cadi Ayyad, Safi, Maroc
Benabderrazik Radia
r.benabderrazik@uca.ac.ma
FSJES, Université Cadi Ayyad, Marrakech, Maroc

Abstract

The "Water Highways" project (WH), is a pillar of the national water policy in Morocco. It aims to transferring surplus water between water basins. The implementation of WH generates substantial governance challenges, as it exceeds the scope of action of traditional river basin agencies, thus requiring institutional restructuring and legislative updating. In order to investigate the systemic integration of the WH within the legal and institutional framework, the research project « AutEauGov » funded by the University of Cadi Ayyad, takes a distinctly multidisciplinary and transversal methodological approach, integrating Law, Economics, Geography, and Ecological Sciences.

Keywords: water transfer, law, Morocco, AuTeauGov project.

0000-0001-5300-5866
0009-0001-4936-4708
0000-0002-7378-549X
0009-0004-9954-8582

Introduction

Les “autoroutes de l’eau” (AE) font désormais partie intégrante de la politique de l’eau au Maroc. Elles consistent à transférer les eaux excédentaires d’un bassin hydrographique vers un autre bassin hydrographique déficitaire (figure 1).

Une première étape a été franchie en dotant le bassin de Bouregreg des eaux excédentaires du bassin de Sebou. Mais les AE interrogent le droit, les autres instruments de régulation de l’action publique et les modes de gouvernances des territoires et des ressources naturelles. Elles représentent un défi aux preneurs de décision dans le sens où elles peuvent dépasser les juridictions des agences de bassin hydrauliques. De ce fait, elles requièrent des approches de gouvernance nouvelles, bien qu’elles s’appuient sur des principes juridiques sous-jacents. Les AE nécessiteront donc une restructuration des institutions responsables de la gestion de l’eau, mais aussi des lois qui leurs servent d’assise juridique.

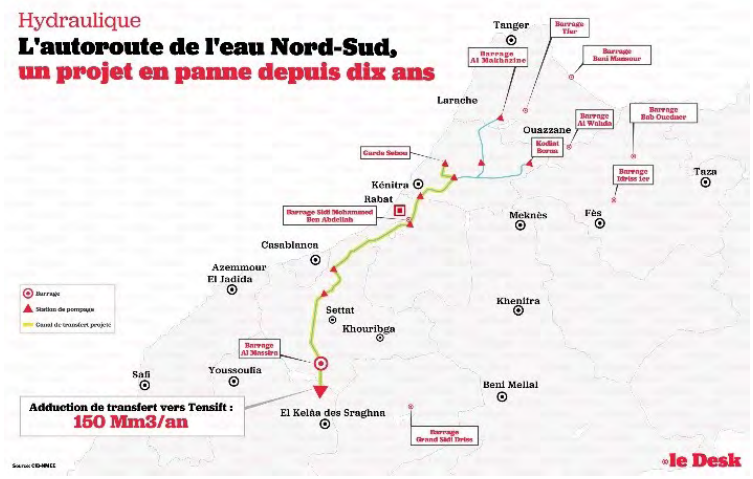

Figure 1 : L’autoroute d’eai Nor-Sud (Source : Sbiti S., 2022)

Etat de l’Art et Problematique

Sur le plan de la gouvernance des ressources en eau, la littérature existante est assez riche (CESE, 2020). Cependant, cette littérature dissocie d’une part l’analyse des modes de gouvernance du territoire, de ceux portant plus particulièrement sur la ressource en eau. En effet, chacun de ces deux aspects est traité par des branches différentes du droit (droit foncier, aménagement du territoire, droit de l’environnement, droit administratif…).

Cette approche sectorielle ne peut s’appliquer à l’analyse des autoroutes de l’eau dans le sens où celles-ci s’imbriquent si fortement dans le tissu de gouvernance du territoire et nécessitent donc une démarche d’analyse globale (approche transversale). Par ailleurs, les travaux académiques portant sur la gouvernance de la ressource hydrique intègrent peu l’approche pluridisiciplinaire (droit/science, sciences politiques/géographie/économie). De même, pour qu’elles soient économiquement viables, les autoroutes de l’eau gagneraient à mieux s’ancrer dans les tissus juridique et institutionnel existants. Cet aspect est quasiment absent de l’analyse en sciences sociales au Maroc. En effet, bien que le droit de l’eau ait fait l’objet de plusieurs travaux académiques (Chaouni, 2005, Tazi Sadek, 2008), la question des autoroutes de l’eau n’a pas encore été traitée par une étude juridique complète.

Ceci contraste avec ce qui se fait en droit comparé. En effet, que ce soit en France (Kernéis, 2011), aux Etats Unies (Woodhouse & Muller, 2017), dans les pays d’Amérique latine (Lopez et al, 2019) ou au Moyen Orient (Abbas et al, 2023), plus proches de nous en termes de situation hydroclimatique, les autoroutes de l’eau ont suscité l’intérêt des chercheurs qui ont analysé leurs faisabilité sur le plan institutionnel (Daoud, Dehnavi, & Ribbe 2022) ainsi que les avantages socio-économiques (couts-avantage) qu’elles représentent.

Methodologie

En se basant sur une grille d'analyse pluridisciplinaire (droit, politiques publiques, économie, géographie et sciences de la vie et de la terre), cette étude vise à identifier les opportunités, les enjeux et les défis qui pourraient faciliter et/ou entraver le projet des AE au Maroc en partant de l'exemple de l'AE dont bénéficiera la région Marrakech-Safi.

Cette étude mettra l'accent sur les synergies et/ou divergences des différentes stratégies de développement menées par le pays en termes de leurs territorialisation dans le domaine des AE. Il s'agira d'identifier dans le droit de l'eau, de l'aménagement du territoire, des politiques publiques, de l'urbanisme, de l'environnement, de la fiscalité, du foncier et le droit constitutionnel, notamment, les outils qui peuvent aider ou entraver un tel chantier. Cette analyse prendra en compte le droit comparé et le droit international. Elle s'appuiera sur les données des sciences écologiques et des sciences économiques, pour apporter un éclairage complet basé sur l'analyse du terrain.

La région Marrakech-Safi fourni un terrain propice pour une telle analyse dans le sens où elle est la cible de plusieurs stratégies hydriques (déssalement/autoroute de l'eau).

Notre étude propose un cadre méthodologique pour évaluer la politique des autoroutes de l'eau sur les plans juridique, écologique et économique en partant du cas de la region Marrakech-Safi.

Dans ce sens, on abordera la question de la territorialisation des politiques publiques de l'eau notamment la stratégie des autoroutes de l'eau et de la désalinisation de l'eau de mer tout en questionnant leurs synergies.

Objectifs et Resultats Attendus

L'objectif de cette analyse interdisciplinaire est de suggérer des pistes d'aide à la decision (Policy capacity) (Hassenteufel, 2021), et de donner une vision claire des enjeux qui entourent ce nouveau chantier stratégique pour le Maroc.

En effet, il s'agit d'apporter un éclairage aux preneurs de décision sur l'ancrage institutionnel des AE, notamment en termes d'attributions, de champs d'action, de synergies et d'amélioration du dispositif entourant les AE pour une bonne gouvernance telle que prônée par la Constitution.

Cette étude vise à :

1. faire l'état des lieux écologique, socio-économique, juridique et institutionnel de l'autoroute de l'eau dont bénéficiera la région Marrakech –Safi.

2. déceler les opportunités d'une bonne intégration de ce projet dans le tissu socio-économique, juridique et institutionnel.

3. proposer des pistes d'amélioration (et d'innovations) des cadres juridique et institutionnel encadrant les autoroutes de l'eau ainsi que des mesures pour minimiser les éventuels impacts négatifs du projet sur le milieu naturel.

Sur plan socioéconomique, cette étude vise à :

- Évaluer l'impact sur les communautés locales (en termes d'accès à l'eau, d'emploi, de conditions de vie).
- Analyser les effets sur les secteurs économiques (agriculture, industrie, services, tourisme).
- Analyser l'impact des changements dans la disponibilité de l'eau sur les prix de l'eau et les habitudes de consommation.

- Évaluer l›acceptabilité sociale du projet (perceptions, préoccupations, attentes des populations). (Jessy Bailly, 2024)

Sur le plan écologique, cette analyse vise à :

— **Identification et évaluation des impacts environnementaux** et analyse des effets directs et indirects du projet sur les écosystèmes, la biodiversité, les ressources en eau, le sol, l'air et les communautés humaines.

— **Proposer des mesures de mitigation** et développer des stratégies pour éviter, réduire ou compenser les impacts négatifs identifiés, telles que la restauration des habitats, la création de passages pour la faune, et la gestion durable des ressources en eau.

Conclusion

L'étude des enjeux juridiques, socio-économiques et environnementaux liés aux autoroutes de l'eau représente une démarche scientifique inédite, aucun travail académique n'ayant jusqu'à présent exploré cette thématique. Il est pourtant essentiel, dès la phase initiale de ce projet stratégique pour le Maroc, d'analyser son contexte juridique et les obstacles potentiels afin de les anticiper et d'y apporter des solutions. Le cadre juridique applicable aux autoroutes de l'eau se révèle en effet complexe. Notre approche consiste à mener une analyse approfondie de ce cadre juridique, en prenant comme étude de cas la région de Marrakech-Safi. Cette analyse sera combinée à des données de terrain (socio-économiques et environnementales) et enrichie par un traitement cartographique. L'outil cartographique contribuera à une meilleure intelligibilité des mécanismes juridiques et institutionnels applicables.

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Análise estatística do impacto das alterações climáticas na distribuição espaço-temporal da precipitação no norte da região de Abda (província de Safi, Marrocos)

Analyse statistique de l'impact des changements climatiques sur la répartition spatio-temporelle des précipitations dans le Nord de la région de Abda (Province de Safi – Maroc)

El Mehdi El Joumdouni
Abdessamad Charif
Abdelghani Qadem
El Outassi B.
Hamila Ait Malek
Mohamed Chaibi
Fatima El Bchari

Resumo

Este estudo analisa a variabilidade espacial e temporal da precipitação na região norte de Abda (Província de Safi, Marrocos) entre 1961 e 2020. Utilizando métodos estatísticos como análise de dupla massa, método CUSUM e análise de frequência, os resultados revelam fortes flutuações interanuais e regionais, com alternância de períodos húmidos e secos. Estas variações afetam diretamente os recursos hídricos e as atividades agrícolas num contexto semiárido cada vez mais condicionado pelas alterações climáticas. Os resultados evidenciam a necessidade de estratégias adaptativas de gestão da água para mitigar os impactos da seca e promover a sustentabilidade.

Palavras-chave: variabilidade pluviométrica, alterações climáticas, Marrocos, região semiárida, recursos hídricos.

Abstract

This study analyzes the spatial and temporal variability of rainfall in the northern Abda region (Safi Province, Morocco) between 1961 and 2020. Using statistical techniques such as double-mass analysis, the CUSUM method, and frequency analysis, the results reveal significant interannual and regional fluctuations, with alternating wet and dry periods. These variations directly affect water resources and agricultural activities in a semi-arid context increasingly affected by climate change. The findings emphasize the need for adaptive water management strategies to mitigate drought impacts and ensure sustainable resource use.

Keywords: rainfall variability, climate change, Morocco, semi-arid region, water resources.

El Mehdi El Joumdouni
eljoumdouni.elmehdi.phd@usms.ac.ma
Abdelghani Qadem
Laboratoire DLRH, Faculté des Lettres et Sciences Humaines, Université Sultan Moulay Slimane, Beni Mellal, Maroc
Abdessamad Charif
a.charif@uca.ac.ma
El Outassi B.
b.eloutassi.ced@uca.ac.ma
Hamila Ait Malek
h.aitmalek@uca.ac.ma

Mohamed Chaibi
chaibimohamed@gmail.com
Fatima El Bchari
Equipe de recherche GEGEL, Faculté Polydisciplinaire, Université Cadi Ayyad, Safi, Maroc

0000-0002-0185-2593
0000-0003-0942-1015

Introduction

Le climat joue un rôle fondamental dans les conditions de vie et influence les réponses biologiques et écologiques des écosystèmes à l'échelle mondiale (Root *et al.*, 2003). Son impact s'étend à divers domaines, notamment les ressources en eau, l'agriculture, la sécurité alimentaire, la santé et la stabilité socio-économique. Depuis la fin du XIXe siècle, le climat mondial est marqué par un réchauffement global dont les effets varient selon les hémisphères. D'après le dernier rapport du GIEC (2023), cette évolution climatique accentue la fréquence et l'intensité des événements extrêmes, augmentant ainsi la vulnérabilité des populations. La fréquence des sécheresses, inondations et ouragans souligne la nécessité d'approfondir les recherches sur les variations climatiques, incitant la communauté scientifique à intensifier ses efforts pour mieux comprendre et anticiper ces changements à l'échelle globale et locale.

Par sa situation géographique sur la rive sud de la Méditerranée, le Maroc n'échappe pas aux effets du changement climatique global (Knippertz *et al.*, 2003 ; Sebbar, 2013, Bahou, 2002). Son climat, influencé par les masses d'air maritimes au nord et à l'ouest et par les influences sahariennes au sud, présente une forte variabilité régionale, marquée notamment par une diminution des précipitations en allant du nord vers le sud. Ces variations spatio-temporelles du régime pluviométrique affectent de nombreux secteurs d'activité, notamment l'agriculture, l'industrie, etc…, impactant ainsi la situation socio-économique du pays.

Dans ce contexte, la présente étude vise à analyser la variabilité spatiale et temporelle du régime pluviométrique annuel dans la région nord de Abda (Province de Safi) sur la période 1961-2020. Pour ce faire, l'analyse s'appuie sur les données de cinq stations climatologiques sélectionnées en raison de la continuité et de l'homogénéité de leurs séries de mesures.

Presentation de la Zone d'Etude

1. Contexte géologique et géomorphologique

La zone d'étude, située dans la partie nord de la région de Abda, appartient au domaine mésétien, caractérisé par un socle paléozoïque recouvert de formations mésozoïques et cénozoïques tabulaires bien développées. Administrativement, elle relève de la province de Safi (Région Marrakech-Safi) et couvre les communes de Hrara, Msabih, Bkhati, Goraani, Lahdar, Chahda, Sidi Aïssa, Moul Bergui, Sâadala, Ayir et Beddouza, et le centre urbain de Jemaâ Shaim (Figure 1).

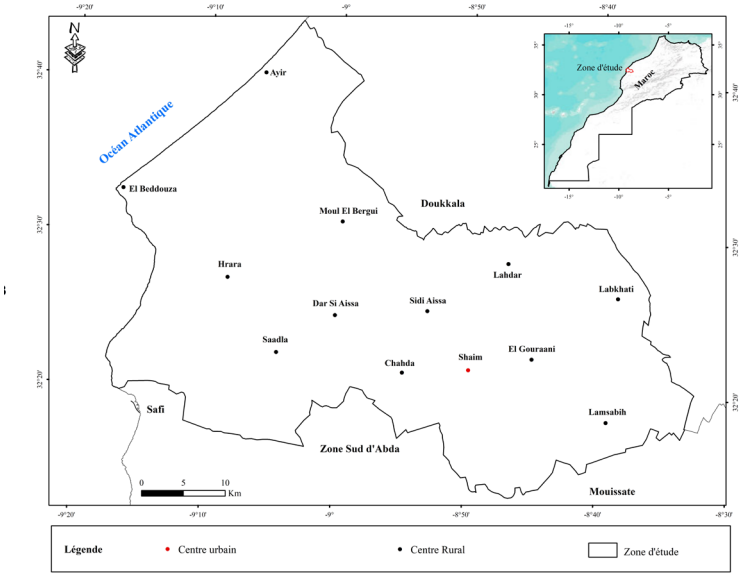


Figure 1 . Localisation du secteur d'étude

D'un point de vue géomorphologique, la zone d'étude se divise en deux grandes unités : l'arrière-pays et la zone littorale. L'arrière-pays est marqué par des plateaux issus d'un comblement par des colluvions anciennes et récentes (Ouadia, 1998), présentant une topographie irrégulière ponctuée de dayas et délimitée

par des escarpements d'origine tectonique ou fluviatile (Gigout, 1951). Le littoral, quant à lui, se caractérise par un relief ondulé dominé par des dunes consolidées datant du plio-quaternaire, orientées selon un axe NNE-SSW. Les dépressions inter-dunaires y accumulent un sol rouge, issu de la décalcification des dunes, où les eaux de pluie convergent et s'infiltrent. Les côtes présentent une morphologie variée, alternant entre des falaises rocheuses, parmi les plus hautes du Maroc, et des plages sableuses, telles que celles de Karam Daif, Cap El Beddouza et Lalla Fatna. Entre Ayir et Cap El Beddouza, une dépression, appelée Oulja, sépare la falaise morte de la mer (Ouadia, 1998).

2. Le contexte climatique

La zone d'étude, située dans la partie nord de la région de Abda, est soumise à un climat semi-aride à influence océanique, caractérisé par des précipitations irrégulières variant entre 250 et 400 mm/an, principalement concentrées entre octobre et avril. Les températures présentent des contrastes saisonniers marqués, avec des maximales dépassant 35 °C en été, notamment lors des épisodes de chergui, et des minimales avoisinant 5 °C en hiver. L'influence océanique se traduit par des vents dominants d'ouest et de nord-ouest, qui atténuent les températures sur le littoral, tandis que les vents sahariens accentuent l'aridité dans l'arrière-pays. L'humidité relative est plus élevée sur la frange côtière, atteignant jusqu'à 80 % en hiver, alors qu'elle diminue à l'intérieur des terres. En raison du fort ensoleillement et des températures élevées, l'évapotranspiration est importante, limitant l'efficacité des précipitations pour l'alimentation des ressources en eau. Ce climat, marqué par une aridité relative tempérée par l'influence maritime, impacte directement les ressources hydriques de la région.

Methodologie

Afin de définir les caractéristiques climatiques de la zone d'étude, cinq stations météorologiques ont été sélectionnées, disposant de longues séries d'observations. Le choix de ces stations a été basé sur plusieurs critères, notamment leur localisation, leur proximité avec la zone d'étude, la disponibilité de séries chronologiques longues et la qualité des données.

L'analyse des données a permis d'identifier une période commune entre la majorité des stations, s'étendant de 1960/61 à 2020/21 (soit 61 ans). Cette période a été retenue comme référence pour la caractérisation du régime pluviométrique de la zone d'étude.

Des méthodes statistiques largement appliquée dans les études de la variabilité climatique ont été utilisées, à savoir :

la méthode des doubles cumuls (Kohler, 1949 ; Searcy, & Hardison, 1960) utilisée pour détecter les incohérences et les ruptures dans une série de précipitations en comparant les cumuls des précipitations d'une station donnée avec ceux d'une station de référence. Dans ce contexte, la station de Safi a été choisie en raison de la continuité et de la fiabilité de sa série de données sur une période de 61 ans. Elle servira ainsi de référence pour la comparaison avec les autres stations.

la méthode de CUSUM (Equ.1), proposée par Lettenmeyer en 1976, et adaptée aux données hydro climatiques en France par François Gille et Zumstein en 1993. Cette méthode est définie comme étant l'écart du cumul des valeurs (Cj) avec la droite moyenne, et vise à évaluer l'hétérogénéité interne de la série en se basant sur la définition d'un intervalle de confiance (bande passante Cjx, Équ. 2) (François *et al.*, 1993).

Equ.1 : $$CUSUM = \sum_{i=1}^{j} P_i - (Pm \times j)$$

Avec

$\sum_{i=1}^{j} P_i$: Somme cumulée des précipitations jusqu'à l'année j.

Pm : Moyenne des précipitations sur toute la période.

j : Rang de l'année en cours dans la série.

Equ.2 :

$$Cjx = \pm S \times \left(\frac{u\sqrt{N}}{4}\right) + \frac{u^2}{2\sqrt{2}} + \frac{u^3}{8\sqrt{N}}$$

Avec

S : Écart-type des précipitations.

u : Variable de Gausse (95 % → u=1.69).

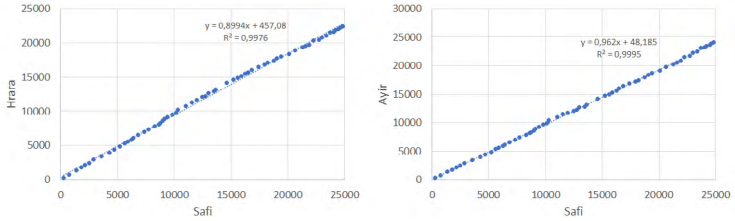
N : Nombre total d'années.

Resultats et Discussion

1. Homogénéité des totaux annuels des précipitations

La méthode des doubles cumuls a été employée pour vérifier l'homogénéité des totaux annuels de précipitations de la station de Safi choisie comme station de référence en raison de la continuité et la fiabilité de la série de données (1960-61/2020-21). Elle servira de base de comparaison par rapport aux autres stations.

Les résultats obtenus (Figure 2) montrent que les courbes représentant les valeurs cumulatives des précipitations enregistrées par les stations météorologiques retenues suivent une trajectoire quasi rectiligne, avec des coefficients de corrélation (R^2) supérieurs à 99%. Cela confirme l'homogénéité des séries à un seuil très significatif et que les mesures pluviométriques annuelles sont exemptes d'erreurs significatives, ou du moins ne présentent pas de données aberrantes



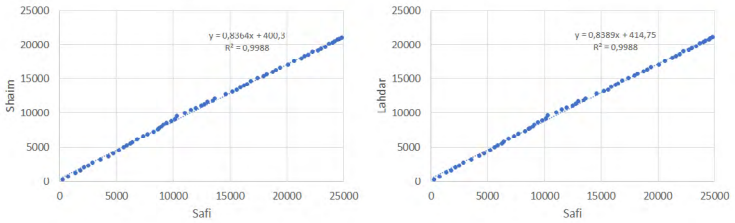


Figure 2. Test d'homogénéité des stations Hrara, Shaim, Ayir et Lahdar par rapport à la station de Safi

2. Variabilité des précipitations

L'analyse des précipitations dans la zone étudiée révèle une forte variabilité spatio-temporelle, avec des disparités notables entre les zones côtières et l'intérieur des terres. La moyenne annuelle des précipitations est d'environ 365 mm, alors que sa répartition varie considérablement d'une station météorologique à l'autre.

2.1. La variabilité annuelle

La variabilité interannuelle des précipitations dans la région d'étude est mise en évidence à partir des données des stations sélectionnées (Figure 3).

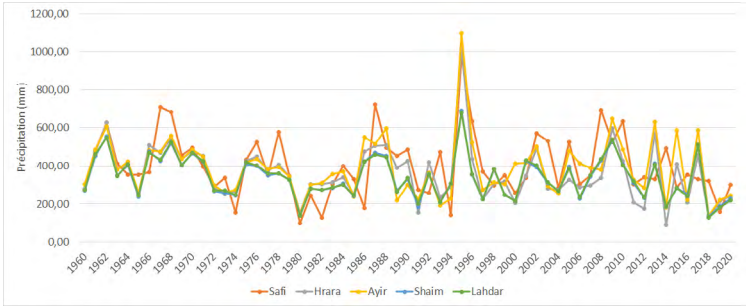


Figure 3 . La variabilité interannuelle des précipitations dans la région d'étude

D'après la figure ci-dessus, on observe une grande irrégularité interannuelle des précipitations. En effet, les précipitations annuelles des cinq stations, présentent des fluctuations remarquables, avec des écarts importants entre les valeurs extrêmes (1095 mm à Ayir et 681 mm à Lahdar) (Cf. Figure 3). La variabilité annuelle des précipitations, est particulièrement marquée à mesure que l'on passe de la zone littorale vers l'arrière-pays. Le coefficient de variation atteint 42.5% à Safi, 41.5% à Ayir et 34% à Shaim (Table 1).

L'analyse des données de précipitations annuelles enregistrées à Safi entre 1960 à 2020 met en évidence une variabilité interannuelle significative, avec des années particulièrement marquées par des précipitations extrêmes. Par exemple, l'année 1995 enregistre une valeur maximale de 971 mm, tandis que 1980 et 1974 affichent des précipitations minimales de 100,4 mm et 155,5 mm respectivement.

	Max	Min	Moy	Ecart-type	Coefficient de variation (%)
Safi	971	100	394,15	167,41	42,47
Hrara	1020	91	355,70	148,85	41,85
Ayir	1095	140	381,73	158,49	41,52
Shaim	690	135	333,94	113,21	33,90
Lahdar	681	130	334,91	112,61	33,62

Tableau 1 . Caractéristiques pluviométriques des 5 stations: Safi, Ayir, Hrara, Shaim et Lahdar.

En effet, la forte variabilité interannuelle est une caractéristique des précipitations méditerranéennes (Driouech, 2010). Cependant, cette variabilité ne permet pas de discerner clairement la succession des années sèches et humides, et l'identification de périodes homogènes s'avère complexe.

Cette variabilité peut être abordée par la méthode du CUSUM dont l'objectif est de déterminer l'hétérogénéité interne de la série étudiée.

Cette méthode illustre clairement les tendances sèches et humides pour les données des précipitations des cinq stations. Les valeurs calculées de Cjx ont permis de fixer le seuil de l'homogénéité qui prend en considération la variation de l'écart type et de la moyenne (Figure 4).

Figure 4 . CUSUM de la série des précipitations observée à la station de Safi, Hrara, Ayir, Shaim et Lahdar entre 1960-61 et 2020-2021.

Les tendances sèches sont représentées par des segments de droite aux pentes négatives, alors que les tendances humides correspondent aux pentes positives. L'allure générale des CUSUM est très proche pour les cinq stations (Figure 4-F), on peut identifier :

— Une succession d'années humides de 1960-61 à 1970-71.

— Une succession d'années sèches de 1971-72 à 2007-08 interrompue par quelques années avec une pluviométrie moyenne et une année exceptionnelle très humide (1995-96).

— Une succession d'années humides de 2008-09 à 2010-11 suivie d'une période sèche depuis 2011 jusqu'à 2020.

En effet, ces intervalles sont similaires à ceux observés dans les études antérieures sur les tendances pluviométriques au Maroc.

2.2. Analyse fréquentielle des précipitations annuelles

Une autre approche pour étudier la variabilité d'une série de données est l'analyse fréquentielle. Il s'agit d'une méthode statistique prédictive qui consiste à examiner les événements passés caractéristiques d'un processus donné afin de déterminer les probabilités de leur apparition future (El Ghachi & Morchid, 2015). Cette approche prédictive est particulièrement pertinente dans le cadre des études sur la gestion des ressources en eau.

Les données de la station de Safi ont été ajustées à cinq lois statistiques : loi Normale, loi Log-normale, loi de Gumbel, la loi de Halphen et la loi de Weibul. L'ajustement des distributions empiriques et théoriques a été réalisé à l'aide du test d'adéquation du Khi2. Le meilleur ajustement a été obtenu avec la loi de Gumbel (Figure 5).

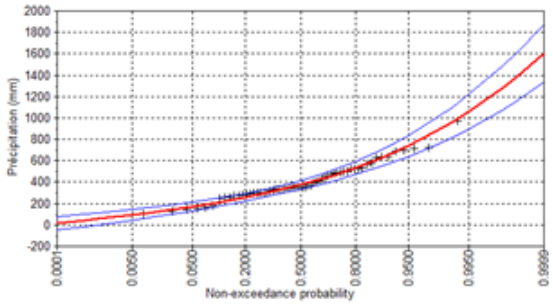


Figure 5 . Ajustement statistique des pluies annuelles de la station de Safi (1960 - 2020) - Loi de Gumbel

Cette méthode nous a également permis de déterminer les périodes de retour des précipitations annuelles à la station de Safi (Figure 6 & 7).

L'analyse des précipitations en fonction des périodes de retour révèle des variations marquées entre les années de fortes pluies et celles de sécheresse. L'année 1995, avec un cumul exceptionnel de 970,6 mm, correspond à une période de retour proche de 100 ans, selon les seuils établis (entre 821 mm et 1110 mm). Les années 1987 (721,8 mm) et 2008 (694,8 mm), se situent également dans des classes de retour élevées, estimées entre 10 et 50 ans.

Les précipitations enregistrées en 1967 (710,9 mm), 1978 (579 mm) et 2010 (633,9 mm) sont quant à elles proches des valeurs correspondant à des périodes de retour de 5 à 20 ans, notamment autour du seuil médian de 637 mm observé pour un retour de 10 ans. En revanche, certaines années se distinguent par des déficits pluviométriques très prononcés, notamment 1980 (100,4 mm) et 1974 (155,5 mm), qui se situent bien en dessous des seuils de référence, indiquant des épisodes de sécheresse extrême, probablement associés à des périodes de retour supérieures à 100 ans. De même, les années 1986 (177,1 mm) et 1994 (142,2 mm) présentent des précipitations exceptionnellement faibles, caractéristiques d'événements rares et critiques du point de vue hydrologique.

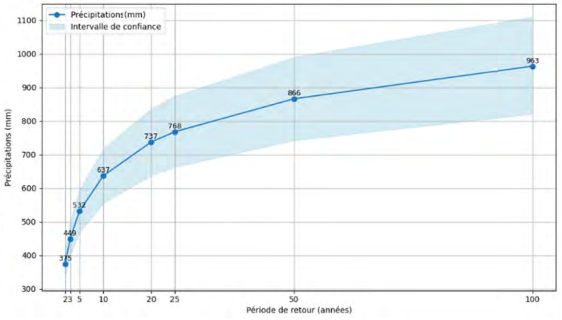


Figure 6 . Précipitations extrêmes dans la station de Safi selon la période de retour

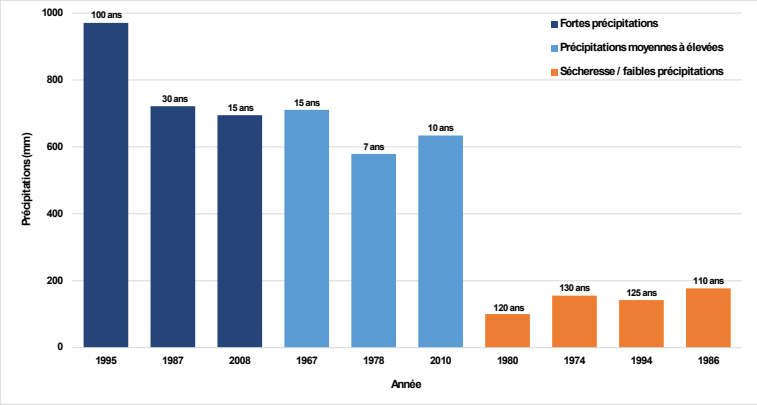


Figure 7 . Précipitations annuelles et périodes de retour estimés

2.3. La variabilité mensuelle

L'étude des précipitations moyennes mensuelles permet de mieux comprendre la répartition des pluies au cours d'une année hydrologique.

La figure 8 illustre la variabilité spatio-temporelle des précipitations mensuelles entre 1961 et 2020 dans les cinq stations : Safi, Ayir, Hrara, Shaim et Lahdar.

Les précipitations suivent un régime méditerranéen marqué par une saison humide (octobre-mars) et une saison sèche (avril-septembre). Le pic pluviométrique est atteint en janvier, avec environ 471 mm à Safi, tandis que les autres stations enregistrent des valeurs inférieures mais relativement similaires. La période humide débute en octobre, atteint son maximum en décembre et janvier, puis diminue progressivement à partir de février. En revanche, les mois de mai à août sont caractérisés par des précipitations inférieures à 50 mm, traduisant des conditions arides estivales. Safi, Ayir et Hrara se distinguent par des valeurs plus élevées en raison de l'influence océanique, tandis que les stations plus continentales enregistrent des précipitations modérées. Cette concentration hivernale des pluies a un impact direct sur la gestion des ressources en eau et l'agriculture locale, tandis que l'analyse des tendances temporelles pourrait révéler d'éventuelles modifications du régime pluviométrique liées au changement climatique.

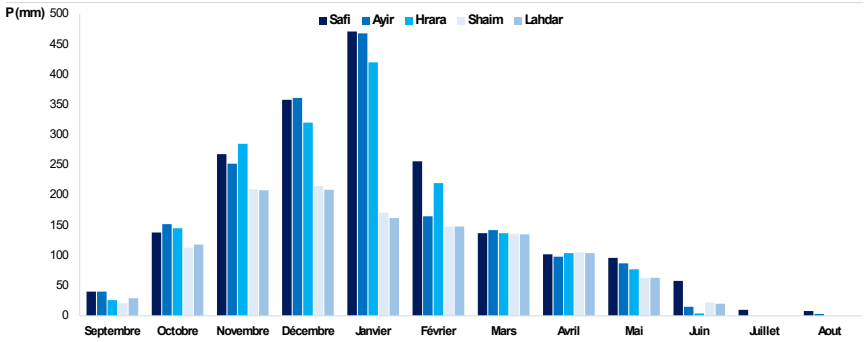


Figure 8 . Distribution mensuelle des précipitations (1960-61/2020-2021)

La répartition spatiale des précipitations dans le secteur d'étude met en évidence clairement l'impact de la situation géographique sur leur distribution. En effet, la zone ouest, littoral, reçoit des précipitations plus importantes, atteignant en moyenne 400 mm. En revanche, la plaine centrale, située **à** l'est et au sud-est, est plus sèche, avec une moyenne d'environ 340 mm de précipitations (Figure 9).

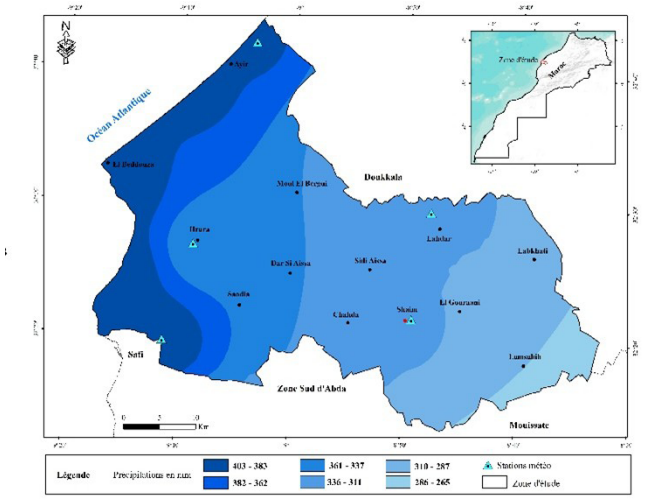


Figure 9 . Carte des précipitations moyennes annuelles sur la période 1960-2020.

Conclusion

L'analyse de la variabilité spatio-temporelle du régime pluviométrique dans la région nord de Abda (Province de Safi) sur la période 1961-2020 a révélé d'importantes fluctuations des précipitations, caractérisées par une forte variabilité interannuelle et une distribution géographique inégale.

L'analyse des données des cinq stations climatologiques montre des années particulièrement sèches, comme celles de 1974 et 1980, ainsi que des années exceptionnellement humides, telles que 1995. Cette variabilité, accentuée par des facteurs climatiques complexes, a des répercussions directes sur les ressources en eau, particulièrement dans un contexte où l'aridité croissante dans certaines zones, en particulier l'arrière-pays, limite l'efficacité des précipitations pour l'alimentation du système aquifère.

L'application de méthodes statistiques, telles que les doubles cumuls, la méthode CUSUM et l'analyse fréquentielle, a permis de mieux comprendre ces dynamiques climatiques. Ces approches ont mis en évidence des périodes de sécheresse prolongée (1971-2007) et des périodes plus humides (1960-1970 et 2008-2010), identifiant clairement des tendances climatiques ayant un impact sur la disponibilité des ressources en eau. Par exemple, les années de sécheresse extrême, telles que 1974 et 1980, ont été associées à des périodes de retour supérieures à 100 ans, mettant en évidence des événements climatiques rares mais critiques pour la gestion des ressources hydriques.

Les tendances observées soulignent la nécessité de renforcer les capacités d'adaptation et de gestion des ressources en eau dans cette région semi-aride, où les impacts du changement climatique sont déjà visibles. Ainsi, cette étude constitue une contribution importante à la compréhension de la variabilité climatique de la région et à l'élaboration de stratégies visant à atténuer les effets négatifs du changement climatique sur les secteurs vulnérables tels que l'agriculture, la gestion de l'eau et la sécurité alimentaire. Les résultats de cette analyse appellent à une intensification des recherches et à une collaboration accrue entre chercheurs, gestionnaires des ressources en eau et décideurs afin d'anticiper et d'adapter la gestion des ressources naturelles face à ces défis climatiques.

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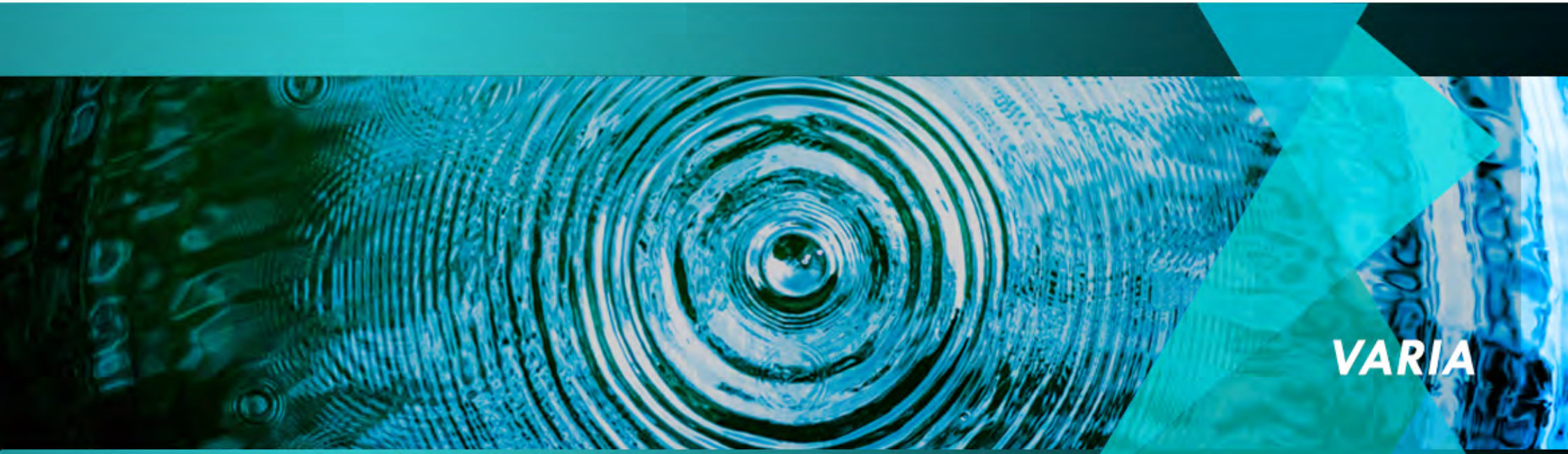

VARIA

A importância das grandes florestas tropicais e a segurança ambiental: perspectivas das florestas tropicais na região dos Grandes Lagos

The importance of large tropical forests and environmental security: perspectives on tropical forests in the Great Lakes region

João Carlos Marques Simões

Resumo

O estado atual do ambiente em África é profundamente preocupante. Pese embora, se trate de um continente com um rico património natural, África enfrenta uma severa crise ecológica. Na região da África tropical, as florestas são recursos de extrema importância não só local, como global, desempenhando entre outras funções, o papel de sumidouro de dióxido de carbono. Nesse sentido, é analisado o papel das pressões antropogénicas nas florestas dos Grandes Lagos africanos, discutindo-se desde as dinâmicas de conflitualidade regional até aos processos de degradação ambiental e desflorestação regional.

Palavras-chave: Burundi; Florestas; Grandes Lagos; República Democrática do Congo; Ruanda.

Abstract

The current state of the environment in Africa is deeply worrying. Despite being a continent with a rich natural heritage, Africa is facing a severe ecological crisis. In tropical Africa, forests are extremely important resources, both locally and globally, playing the role of carbon dioxide sink, among other functions. With this in mind, the role of anthropogenic pressures on the forests of the African Great Lakes region is analyzed, taking into account the dynamics of regional conflicts and the processes of environmental degradation and regional deforestation.

Keywords: Burundi; Democratic Republic of Congo; Forests; Great Lakes; Rwanda.

João Carlos Marques Simões
Doutorando em Relações Internacionais no Instituto Superior de Ciências Sociais e Políticas

0000-0002-7859-4668

1. Introduction

The 21st century has been the century of new threats. The international system is now facing a new type of threats (mainly unconventional threats), for which it is still largely unprepared.

This set of unconventional threats constitutes a set of polycrises, each of which is a polycrisis in itself. More specifically, it concerns climate change and its derivative phenomena, energy security and the transition to a green world, food security, new migratory flows, including climate-induced migratory flows, and also, to a large extent, disputes over resources and, finally, health security.

Most of these threats are closely related to the environment. And, in reality, it is only the environment that allows other traditional threats to exist, evolve, and change, since it is the environment's balance that allows life on our planet. For this very reason, it is important to understand how the environment is linked to security, an issue that will be analyzed in the course of our conceptual framework.

Forests are an important natural component, playing a vital role in sustaining life on Earth. According to Pereira (2014, p.13), "they cover approximately 1/3 of the land surface, contain about 70% of biomass, harbor a substantial portion of terrestrial biodiversity, influence the water balance and climate, and contribute to the balance of the biosphere through their role in the global carbon cycle".

Later, it will be demonstrated that forests are not only an important natural component with ecological functions. Wood, for example, has an important significance for humanity, from contributing as a fundamental element of construction to being an important fuel. But forests, specifically through wood, have also been at the root of the great socio-political revolutions of the last two centuries.

Forests are also a source of various other natural resources and goods, such as cork, mushrooms, fruits and plants, pastures, among many others. Despite their high value, forests face significant challenges. First and foremost is deforestation, because, as Pereira (2014, p.14) points out, "the history of humanity is a narrative of deforestation," since forests can be an obstacle to the movement of people and goods, vast areas of pasture and forest have been burned in the eternal struggle for human domination over nature (Williams, 2003). However, forests also face other challenges, such as climate change, global warming, and increasing demographic pressure, among others.

Forests also make important contributions to sustaining life on Earth through photosynthesis. Among the world's large green areas, some receive particular attention due to their size and importance, such as the Amazon rainforest and the forests in the African Great Lakes region. On the other hand, the current state of the environment in Africa is deeply worrying. Although it is a continent with a rich natural heritage, Africa faces a severe ecological crisis. In this regard, our goal is to analyze the geopolitical importance of the large tropical forests in the African Great Lakes region in relation to regional security in the context of human security.

The article is divided into five sections. The first section discusses the implications of environmental security, addressing the evolution of environmental awareness and the various risks faced by international society. The second section analyzes the global importance of large forests, while the third section analyzes the dynamics of insecurity and instability in the African Great Lakes region. In the fourth and fifth sections, the relationship between climate change and anthropogenic pressures on tropical forests is analyzed, with particular emphasis on African tropical forests.

As far as methodology is concerned, an exploratory and theoretical-descriptive qualitative approach is adopted, focussing on a case study and drawing on bibliographical sources

relating to the African Great Lakes region, particularly Rwanda, Burundi and the Democratic Republic of Congo. The article follows a transdisciplinary rationale, bringing together legal and geopolitical elements, as well as aspects of international relations.

2. Environmental security

Climate change is currently one of the greatest challenges facing the international community, occupying a prominent place on the international political agenda (Climate Change, 2014). In the decades following the Cold War, a new position emerged in the academic arena, as part of international security studies, which was called environmental security.

Soromenho-Marques (2007, p.429) explains that "as the name suggests, it is about the demand for a methodological and categorical compromise between environmental sciences, on the one hand, and a combination of disciplines from the classic areas of security, namely strategy and international relations".

Four factors contributed to the emergence of this new area: (i) the end of the Cold War; (ii) the release of resources; (iii) greater awareness of the global environmental crisis; (iv) and the fragmentation of the international political order.

The end of the Cold War enabled the introduction of new and more diverse concerns into the security agenda of states, but also into the international security agenda. But more than that, the end of the Cold War and the risks of nuclear war were followed by new threats that filled a risk vacuum left by the disappearance of the risks of conflict arising from the Cold War.

The release of resources is not limited to capital resources, but also includes scientific potential, which, as Soromenho-Marques (2007, p.432) points out, "has been directed towards other areas of research, namely in the field of studying the vulnerabilities of our planet, particularly on a global scale".

Greater awareness of the global environmental crisis has been made possible largely through what Soromenho-Marques (2007) refers to as the effect of catastrophe pedagogy. The same author states that

> the accumulation of global indicators of the environmental crisis (...) from acid rain to climate change, has drawn attention to the dangers posed to the stability of an already fragile and uncertain international system by the possible accumulation of symptoms of environmental degradation without an adequate response, with implications and consequences that are not only cross-border but effectively planetary (Soromenho-Marques, 2007, p.432).

The end of the Cold War also meant the breakdown of the existing international order, putting an end to the bipolarity that characterized the Cold War environment and thus allowing greater autonomy of action to states that had previously been relegated to a peripheral role.

In this sense, it is important to highlight some of the factors of human activity that have contributed to influencing the process of climate change, namely: (i) population; (ii) consumerism; (iii) industrialization; (iv) consumption of fossil fuels; (v) large-scale deforestation; among others. According to Rosa et al. (2015), these factors can be classified as anthropogenic drivers of climate pressure, that is, the set of economic, political, cultural, and social factors that directly or indirectly influence the environment.

Similarly, climate change gives rise to a significant set of crises of various kinds, thus taking the form of a polycrisis. Among its effects, the following are particularly noteworthy: (i) changes in precipitation and temperature patterns; (ii) climate-induced conflicts; (iii) climate-induced floods; (iv) climate-induced migrations; (v) scarcity; (vi) instability; (vii) increased intensity and frequency of natural disasters; (viii) degradation of agricultural production and food systems.

It should also be noted that different regions of the world are not all affected in the same way by climate change, nor do they all have the same level of resilience, vulnerability, and capacity to adapt. Several regions and states are more vulnerable to the effects of climate change. According to the IPCC, the average sea level is expected to rise by 6 centimeters per decade throughout the century, putting several states located in coastal regions such as China, India, Bangladesh, Mozambique, as well as most island states, particularly SIDS (Small Island Developing States), under direct threat (Simões, 2024). The next chapter continues with an analysis of the geopolitical value of the world's great forests.

3. The geopolitical importance of large forests

Forests are paradoxical organic structures. They are paradoxical in that, on the one hand, they are important actors responsible for sustaining life on our planet, but on the other hand, they are also important economic assets.

Gomes (2006) considers that the forest is simultaneously a macrosystem and a microsystem, referring to it as "a living machine that shelters small worlds for animal and plant species and provides refuge for humans in moments of leisure" (Gomes, 2006, p.142). This embodies what is essentially the multifunctional nature of forests (Gomes, 2017; Lopes, 2003; Molina, 1998; Pontes, 2020).

On this very issue, Molina (1998) highlights three essential functions. On the one hand, the ecological function of regulating the biosphere; on the other hand, the social function of recreation; and finally, the economic function of exploiting forest resources. It is important to note that the ecological, social, and economic functions are not limited to the examples presented.

So what are we talking about when we use the term forest? The forest is a renewable natural resource, which, as it was mentioned, is essential to the preservation of life on our planet (Oliveira, 2012).

From a legal point of view, forest assets are associated with a high degree of complexity, which is justified by the specific environmental conditions and the "differentiated approach taken in the various legal instruments that deal with them" (Lopes, 2003, p.60). Precisely for this reason, it should be noted that global forest distribution is not uniform, with some forest areas being denser and others less dense.

Therefore, it is understandable that regulations need to be adapted to different forest bodies, for example, as is the case internationally with the political imperative to protect tropical forests.

Why, then, is it important to talk about forests in the context of international relations? First of all, because they are one of the great guarantors of life on the planet, but also because, as Lopes (2003, p. 61) points out,

> their interaction with other environmental components, essential to an integrated and global consideration of the "environment," has contributed to the main problems affecting them, which have widespread spatial impacts, being debated in various forums for discussion and intervention.

Internationally, and in fact, to a large extent similar to other areas of international environmental law, it is only recently that the ecological dimension of forests has been recognized, since until recently (20th century) the prevailing idea was that natural resources were infinite and subject to centuries of excessive exploitation (Gomes, 2006, 2018; Gomes et al., 2021; Gomes & Leong, 2023).

Special mention should be made of Principle 4 of the 1972 Stockholm Declaration, which marks the beginning of a cycle of utopianism in international environmental law and reflects concern for the ecological dimension of forests and the finitude of natural resources, insofar as it includes the "preservation of forest resources in the weighing of economic development

factors" (Gomes, 2006, p.142).

The utopia of Stockholm was followed by the pragmatism of Rio from 1992 onwards, where, precisely taking into account the pessimistic analysis of the global environmental scenario, forests, faced with worsening desertification and the degradation of the ozone layer, were given a new and reinforced role (Gomes, 2006). Regarding these two factors, it is also important to take into account that forests are both hydrological fixers and carbon dioxide sinks, which is why this phase of international environmental law resulted in the Convention on Biological Diversity and the Framework Convention on Climate Change (Gomes, 2006).

It is believed that we still lack a conceptual definition of "forests." In line with Pereira (2014), we start from the idea that there will be general agreement if we consider forests to be ecosystems dominated by trees, the latter being the distinguishing feature from other ecosystems.

Even so, the adoption of a comprehensive conceptual proposal such as the one identified here raises other problems. The definition of forests as a collection of trees may not have a universal interpretation. Take, for example, the case of the cork oak forest. It is certainly considered a forest in Portugal, but would communities from different regions accustomed to different forest landscapes have the same perception of forests? Probably not.

In order to dispel conceptual ambiguities, we refer to two other conceptual proposals, one put forward by the FAO and the other by the UNECE (United Nations Economic Commission for Europe).

Regarding these proposals, Pereira (2014, pp. 15-16) states that

> forests are ecosystems with tree canopy cover exceeding 10% of the land area, which must be at least 0.5 hectares in size. Trees are woody plants that have a stem (trunk) made of wood (or compact woody tissue) and can reach a height of 5m at maturity. This definition includes forests with low tree density (such as montados in Portugal). Artificial stands and young plant communities that have not yet reached the aforementioned dimensions are also considered forests, as well as land whose tree cover has been recently cut but which is located within forest areas.

Consequently, forests are important environmental components. The environment can be analyzed fundamentally through three lines of reasoning. Gomes (1999) talks about the broad meaning, the narrow meaning, and the indeterminate meaning of the environment.

Regarding the broad meaning of the environment, Gomes (1999) states that we must integrate both cultural and natural assets, thus placing factors such as air, water, flora, among others, on the same level as factors such as natural heritage, landscape, or monumental heritage.

The same author adds that "the environment would thus be constituted by the set of natural resources (renewable and non-renewable) and by human actions that have nature as their support or framework" (Gomes, 1999, p.47).

This is a deeply anthropocentric perspective, found in Giannini (1971, 1973, 1976), which integrates the environment into the category of cultural assets. According to this perspective, natural assets are in themselves totally marginal, depending on human action to be integrated into civilizational processes, as Gomes (1999) points out.

In line with Giannini's perspective (1971), Antunes (1998, p.56) states that "we can speak of a unitary category of cultural assets, which includes the environment, since there can be no cultural identity or cultural heritage without the preservation of the environment in which it is incorporated and in which man historically fulfills himself".

From this perspective, nature, as the collective of natural assets, is protected with a view to making natural assets profitable as a means of satisfying the vital needs of human beings, in line with the demands of their standards of living.

In turn, with regard to the narrow meaning of the environment, it is considered to be only the collective set of renewable and non-renewable natural resources, as well as the interactions that occur between these resources (Gomes, 1999).

The environment in a narrow sense is an approach that devalues the capacity of natural resources to satisfy human needs, with natural resources therefore having an autonomous dignity, "which man should respect and promote, because he is part of it as a member of the biotic community" (Gomes, 1999, p.47).

With regard to the environment in an indeterminate sense, Gomes (1999) considers that this is a perspective that sees the environment as an indeterminate descriptive concept, meaning that the environment should be seen, as an open and variable reality depending on the time period and the heterogeneity of environmental components and the relationships established between them.

As Gomes (1999, p.49) points out, "presenting the environment as an indeterminate concept and referring its determination to physical, cultural, economic, and scientific factors is equivalent to leaving room for the adoption of either a broad or a narrow meaning, depending on the — anthropocentric or ecocentric" underlying the environmental legal system under analysis.

It is also important to take into account that the environment is composed of biotic and abiotic components, being closely linked to human culture, its social, political, and economic values, among many others. Thus, biotic components are seen as the set of living organisms, such as fauna and flora. Abiotic components, on the other hand, are those that, although not alive, influence biotic components chemically, physically, and physically-chemically, such as water, air, soil, energy, temperature, pressure, climate, among others.

Having clarified the concepts of environment and forest, we are left with the third initial concept we set out to analyze: the concept of tropical forest. So what is a rainforest? Plotkin (2020) leads us to consider that rainforests are a mixture of reality and imagination, with diverse flora and fauna that contribute to their aesthetic depth. They are located in the tropics, more specifically between the Tropic of Cancer and the Tropic of Capricorn, and are hot, humid, and characterized by intense rainfall (Allaby, 2006).

The tropics are mainly covered by ocean water, which affects the conditions in which tropical forests grow. And even though the tropics are known for heavy rainfall, tropical forests cover a much smaller area than it would be expected (Allaby, 2006).

Tropical forests are spread across five regions: (i) America and the Caribbean; (ii) Africa and Eastern Madagascar; (iii) India, Malaysia, and other parts of Asia; (iv) Australia; (v) and some islands in Oceania and Hawaii. Even within these regions, however, the distribution of forests is not equitable, with around 57% of these forests found in the Americas, around 25% in Asia, around 18% in Africa, and the remainder divided between Australia and the islands of Hawaii and Oceania (Allaby, 2006).

In addition, although these areas are partly covered by tropical forests, not all of them are the same. According to Allaby (2006, p.5) "rainfall is intense and distributed fairly evenly throughout the year in Central America, the Amazon Basin, the Congo Basin, eastern Madagascar and much of Southeast Asia. These are the areas where tropical rainforest" often referred to as tropical rainforest occurs.

The next chapter will analyse the dynamics of insecurity and instability in the African Great Lakes region, as pre-existing factors of instability and insecurity can interact with climate change and environmental degradation to exacerbate a situation of risk and potential crisis or conflict.

4. Insecurity and instability in the African Great Lakes region

The Great Lakes region is located in the Rift Valley in East Africa and has some of the deepest lakes in the world, including the territory of several states: (i) Burundi; (ii) Ethiopia; (iii) Malawi; (iv) Mozambique; (v) Kenya; (vi) the Democratic Republic of Congo; (vii) Rwanda; (viii) Tanzania; (ix) Uganda); (x) Zambia. The various lakes can be grouped into four groups: (i) lakes that flow into the White Nile; (ii) lakes that flow into the Zambezi; (iii) lakes that flow into the Congo; (iv) closed basin lakes. Let's focus on the specific case of the tropical forests of the Democratic Republic of Congo, Rwanda and Burundi. These three states are part of the Nile River basin, but the dynamics related to the Nile's water regime will not be discussed here.

The Great Lakes region has been characterized by recurrent and lengthy conflicts, fostered by the politicization of identity, the internationalization of conflicts, high civil participation in highly violent practices, and the colonial legacy, which has generally contributed to a scenario of political instability throughout the continent (Bernardino, 2008; Pavia, 2021, 2024; Shyaka, 2008). The causes and dynamics of conflicts in the Great Lakes region are complex and diverse, ranging from challenges associated with ethnic divisions, unequal access to natural resources and unequal access to land itself, the internationalization of conflicts, to the erosion of democratic institutions. When ethnic diversity is considered as a driver of political violence, it should be kept in mind that this factor must be integrated into a broader analysis, since it alone should not be sufficient to trigger conflicts. Furthermore, ethnic heterogeneity is not a condition that necessarily condemns a society to violence, just as ethnic homogeneity does not guarantee peace. Even so, the artificial demarcation of borders in various African states, which brings together different and sometimes rival ethnic groups, has been found to be a major driver of political violence (Pavia, 2021, 2024).

In the specific cases of Rwanda, Burundi, the Democratic Republic of Congo and Uganda, conflicts have been motivated by ethnic differences rather than ideology, as well as the ability of leaders to fracture societies and hostile ethnic groups against each other, for example in the case of conflicts between Hutus and Tutsis.

Access to land is also an important driver of conflict in the Great Lakes region. According to Kanyangara (2016) "in Rwanda, unequal access to land is one of the structural causes of poverty that was exploited by those responsible for the genocide. Limited access to land, exacerbated by its unequal distribution, and similar insecurity (...) have been described as key aspects of the 'structural conflict'".

In Burundi too, for example, the unequal distribution of land is a major factor in insecurity, contributing to widespread poverty and disagreements with the government and sections of the national elite.

Similarly, in the Democratic Republic of Congo, land is a major issue for a number of reasons. Firstly, because "insecure or insufficient access to land in many parts of the East is a significant factor in the impoverishment of thousands of people in rural areas and is a 'structural' cause of conflict" (Kanyangara, 2016), and secondly, the contested purchase and extension of agricultural concessions in the Ituri and Masisi regions have also been identified as sources of violence. Finally, the most recent conflicts themselves have contributed to a change in patterns of access to land, firstly through the forced displacement of communities, but

also through changes in the level of authority of administrative leaders (Kanyangara, 2016).

Land disputes are therefore generally understood to be one of the main challenges to sustainable peace. According to Le Billon (2001), it is possible to distinguish between two types of conflicts over access to natural resources. On the one hand, conflicts arising from disputes between two or more states over natural resources located in shared border regions and, on the other hand, conflicts arising from the illegal exploitation of natural resources in order to finance regional conflicts.

With regard to unequal access to natural resources and their overexploitation, it is worth recalling the idea of the natural resource curse, or the paradox of abundance. (Campos et al., 2018; Sachs & Warner, 1995; Veríssimo & Xavier, 2014).

This paradox portrays the idea that countries and/or regions endowed with an abundance of natural resources, be they forest resources or other types of natural resources, tend to show lower economic growth, as well as worse development results, when compared to countries endowed with fewer natural resources.

This theoretical framework has often been applied to the states of the Global South, in particular those of Latin America and sub-Saharan Africa, which are generally endowed with a great diversity of natural resources, but still have lower economic growth and less development than other regions with fewer resources, for example the Asian Tigers (Campos et al., 2018; Pamplona & Cacciamali, 2017; Sachs & Warner, 1995).

However, the relationship between internal instability, weak economic growth and development, and the abundance of natural resources is not entirely straightforward. Bastos and Ferreira (2013) compare the cases of two sub-Saharan African states, Nigeria and Botswana, showing that both are rich in different natural resources: Nigeria in oil, and Botswana in diamonds. The latter has managed to escape the curse of natural resources, showing significant internal stability and positive economic performance

As mentioned earlier, pre-existing factors of insecurity and instability can interact with climate change and environmental degradation to exacerbate a situation of risk and potential crisis or conflict. For this reason, in the following chapter it will be discussed the relationship between climate change and anthropogenic pressure factors in large tropical forests.

5. Climate change, anthropogenic activities and the great tropical forests

Biodiversity hotspots such as lakes, coral reefs and forests, among others, are fundamental to terrestrial sustainability and the maintenance of life on Earth. However, climate change, particularly of an anthropogenic nature, and its effects constitute risk and pressure factors that jeopardize these same biodiversity hubs.

It is also important to take into account that different regions and ecosystems have different degrees of sensitivity, vulnerability and resilience to climate change. Santos (2018, p.167) considers that "the degree to which a given natural or social system is affected positively or negatively by climatic stimuli characterizes its sensitivity to climate change". These same natural and social systems also have distinct traits when it comes to their ability to adapt to the effects of climate change.

To a large extent, it is the combination of the social and natural systems of the various states that determine their sensitivity, vulnerability and capacity to adapt. In fact, in line with Santos (2018), it is possible to consider that the development of these systems is inversely proportional to vulnerability and directly proportional to adaptive capacity, insofar as, as the same author states, "the lower human and material resources of less

developed countries decrease their adaptive capacity, making them more vulnerable to climate change than countries with advanced economies" (Santos, 2018, p.167).

In tropical Africa, the tree is a fundamental element of the entire environmental system. Forests are important ecosystems with high biodiversity. Despite the knowledge of the significant importance of forests, they

> continue to be cut down at a truly mind-boggling and drastic rate: currently, every 10 seconds, an area of rainforest equivalent to the size of a football field is lost, which in turn corresponds to the annual deforestation of an area equivalent to the size of England. As a result, little more than 20% of the forest cover that existed after the last glaciation (Würm) remains on the globe, that is, after the beginning of the current period, the Holocene (Anthropogenic) (Paiva, 2018, p.109).

It was mentioned earlier that human history has been characterized by the continued practice of deforestation, making it clear that there is a relationship, a link between forests, humans, and deforestation.

As Pereira (2014, p.25) points out,

> man's activities have been one of the main factors in deforestation. The repeated felling or destruction of trees at shorter intervals than the time needed for regeneration leads to deforestation. Overexploitation of wood resources, such as to obtain arable land, or space for grazing, or for urban and defense purposes, for example, have been justifications for deforestation.

As mentioned above, for a large part of human history, environmental resources were seen as unlimited (Gomes, 2018), so environmental awareness only really began to develop in the 20th century (Gomes, 2018; Gomes & Leong, 2023).

Even so, despite increased environmental awareness and a vast body of national and international environmental legislation, forest destruction continues to be a reality in various regions of the world today, such as the Amazon, Africa and Southeast Asia.

There are many factors contributing to forest decline and deforestation, from overpopulation and underdevelopment, to cutting down trees for the timber industry, overgrazing, fires and plowing for arable land (Ramade & Caquet, 1995).

Despite the economic added value of using forests, and/or the condition of economic dependence on forest resources, deforestation has a number of negative impacts, which have a profound impact on human beings and their safety, starting with the destruction of habitats and the loss of biodiversity, which is fundamental to human survival. Furthermore, as Seitz (1995, p.209) points out, deforestation "can lead to land erosion, can harden the soil and can make freshwater supplies irregular (...) Sometimes deforestation leads to too much water in the wrong places", potential consequences that can accentuate the effects of pre-existing factors of instability and insecurity and thus contribute to the triggering of crises and conflicts

There is also the danger that deforestation will contribute to accelerating global warming. According to Seitz (1995, p.211), "trees that are burned after being cut down (...) release carbon dioxide into the atmosphere. The great rainforests have been found to contain an enormous store of carbon and have been described by some as the lungs of the Earth, absorbing carbon dioxide and releasing oxygen". Consequently, deforestation, by accelerating global warming, contributes to generating negative effects of its own, which jeopardize environmental and human security in particularly vulnerable regions.

It is mainly in developing states, particularly in the Global South, that forest security remains drastically at risk. Poverty, which manifests itself through economic dependence on forests, is at the heart of the problem of deforestation, as is the case with hunger crises and the population explosion in the Global South.

And while development may be the key to reducing poverty and, consequently, the risks to forests, it can also, as mentioned, be a source of risk, leading to the destruction of forests through economic exploitation.

Another important issue to consider relates to efforts associated with REDD+ (Reducing Emissions from Deforestation and Forest Degradation+). REDD+ was established by the United Nations Framework Convention on Climate Change (UNFCCC) as a mechanism to combat global warming and climate change, succeeding the previous RED and REDD concepts. Since then, many REDD+ projects have been established in several developing countries with abundant forests, many of them in Africa (Flanery et al., 2019; Mbatu 2016, 2019; Mbatu & Eliamini, 2025; Pistorius, 2012).

According to Mbatu and Eliamini (2025), "following the initial draft reports on the UNFCCC REDD+ framework, scholars and forestry practitioners began to focus on Africa and the social, economic, cultural and political vulnerabilities and insecurities of readiness and implementation initiatives on the continent" (p.2). Since then, the literature on how REDD+ projects are developed in Africa and the challenges they present has grown significantly. However, this is an issue that will be discussed further below.

REDD+ reached its current configuration in 2008 during COP14, although the programme formally emerged in 2007, even though informal negotiations on "avoiding deforestation" had been ongoing for over a decade. Since 2007, the programme has undergone changes and expanded its scope, shifting from a focus on reducing emissions (RED) to a focus on reducing emissions from deforestation and degradation (REDD) in 2007 at COP13, and finally shifting to a focus on reducing emissions from deforestation and degradation, plus conservation activities, sustainable management and increasing forest carbon stocks (Mbatu & Eliamini, 2025; Pistorius, 2012).

In the following chapter, this discussion on the nexus between anthropogenic pressure and climate change is continued, applying what has been developed thus far to the specific case of tropical forests in the Great Lakes region.

6. Perspectives on tropical forests in the Great Lakes region

As discussed above, there is a particular interest in the region covered by the Democratic Republic of Congo, Rwanda and Burundi. The massive deforestation in these three states has profound impacts on the region's rainfall regimes, climate and biodiversity (Yohannes, 2008).

These three states cross the tropical rainforest region of Africa. In fact, the Democratic Republic of Congo and Gabon represent two of the nine states that have 80% of the world's tropical forests (Yohannes, 2008).

It is also important to highlight the significance of the Rwenzori Mountains, located on the border between the Democratic Republic of Congo and Uganda. According to Yohannes (2008, p.146), these mountains "covered by a variety of high-altitude cloud forests, are both important climate regulators and food sources. Acting as hydrological towers at the equator, these mountains intercept air and force it to precipitate, "and are therefore referred to by locals as" rain givers".

However, human penetration and deforestation of these ecosystems has jeopardized the services provided by these mountains and their wet forests, which are considered as important as the flow of the Nile itself.

Deforestation in this region began several centuries ago, with the arrival of farmers and pastoralist communities who began deforestation processes to obtain land for cultivation and grazing.

In addition, most of this area was off the slave labor trade routes, so there was a gradual increase in population density in the region, due to the displacement of communities seeking refuge. By the middle of the 20th century, this region had one of the highest rural population densities in Africa.

The increase in population density, accompanied by a consequent increase in the area of cultivated land, has contributed to a significant decline in forest area. By 1980, excluding wildlife conservation reserves and areas set aside for environmental protection, most of the available land in Rwanda and Burundi was being used for human agriculture and pastoralism.

Anthropogenic pressures on the forests were to increase with the development of agricultural production for export. In fact, in 1960, around half of the forests in Rwanda's northern volcanic region were made available for pyrethrum production. Other forest regions in Rwanda were made available for tea production. While in the Democratic Republic of Congo, forest regions were made available for the exploitation of quinine and coffee.

During the 20th century, particularly between the 1960s and the 2000s, there was a great deal of deforestation in the Great Lakes region. For example, during this century Rwanda's forest area fell from 30% to 7% and Burundi's forest area fell from 6% to 2% between 1976 and 1997.

In addition, Butler (2020) identifies some of the main traditional and current drivers of deforestation and forest degradation in the Democratic Republic of Congo: (i) small-scale subsistence agriculture; (ii) deforestation for charcoal and firewood production; (iii) urban expansion; (iv) mining; (v) and in the case of forest degradation, industrial logging.

But the drivers of deforestation and forest degradation in the Democratic Republic of Congo do not stop there. Constant political violence and intensive hunting practices and trade in what is commonly referred to as "bushmeat" also contribute to deforestation and forest degradation

In this scenario, forest degradation and deforestation are threats to the local and regional socio-ecological balance, an aspect which, as Chamard (1995) recalls, was proven by the desertification of parts of the Sahara and Sahel during the drought of 1968.

The current ecological crisis in Africa can only be seen as an accumulation of unresolved local crises that occurred during the second half of the 20th century. The seemingly never-ending population increase and, in particular, the legacy of colonial policies based on a market economy logic based on export agriculture, have contributed to "peasant horticultural crops being relegated to the background and pushed onto more fragile lands" (Bessis, 1995, p.373)

The environmental vulnerability of the Great Lakes region is deeply intertwined with demographic pressures, climate variability, and disputes over access to, control of, and exploitation of natural resources, among other factors. Beyond subsistence agriculture and fuelwood use, the exploitation of minerals such as coltan and cobalt, essential materials for global industries, particularly renewable energies and digital technologies, links deforestation to international supply chains. Thus, forest loss in Central Africa cannot be seen merely as a local environmental issue but as part of a global political economy of resources.

This interconnection also extends to the field of health, since deforestation and habitat fragmentation, and increased bushmeat hunting raise the risk of zoonotic disease transmission, as evidenced by outbreaks of Ebola and other epidemics in forested regions. Consequently, environmental degradation in Central Africa is directly tied to global health security.

At the social level, deforestation disproportionately affects different social groups, particularly vulnerable groups such as women and children in rural areas who depend on forests for fuelwood, food, and water. As forest resources diminish, women and children are forced to travel longer distances for basic needs, intensifying gender inequalities and undermining community resilience.

Efforts to address deforestation have been framed through initiatives such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation), international conservation projects, and the African Union's Agenda 2063. However, these measures often face tensions between conservation, national sovereignty, and local development needs (Gizachew et al., 2017). Regional bodies like the East African Community (EAC) and the Economic Community of Central African States (ECCAS) provide platforms for transboundary cooperation, yet their effectiveness is limited by political instability and competing economic priorities.

In view of the region's environmental vulnerability, it is therefore necessary to try to restore the least degraded ecosystems and reforest forest areas that have been sacrificed to the detriment of economic income. In addition, human resources must be mobilized in order to increase and guarantee the protection of nature and the preservation of biodiversity, as well as ensuring food security for local populations. In essence, priority must be given to promoting the deep-rooted construction of sustainable and lasting economic and social development logics, which are consequently based on principles of intergenerational ethics.

It should also be noted that deforestation and the scarcity of other natural resources increase the potential for regional conflict. This is an environmental multiplier threat associated with a pre-existing escalation of tensions. In other words, the environmental insecurity that stems from the degradation of ecosystems leads to an increase in political, economic and social pressures that might otherwise remain dormant.

With regard to REDD+ in the region, the programme faces significant challenges in East Africa, particularly from the illegal trade in forest products, which threatens protected areas and conserved tree plantations, many of which originate and are traded from the Democratic Republic of Congo (Cavanagh et al., 2015; Mbatu & Eliamini, 2025). It is also important to note here that obstacles to the success of REDD+ programmes are often associated with pre-existing factors of instability, which contribute to the perpetuation of behaviours that undermine the sustainability and protection of forests, such as poverty, agricultural expansion, changing consumption patterns and increased consumerism, market failures, external debt, as well as various other issues associated with the incapacity and inefficiency of government infrastructure (Mbatu & Eliamini, 2025). Additionally, other factors such as restrictions on forest access, land tenure complexity, exclusion and non-community participation in REDD+ project implementation, contextual inequality in benefit sharing, and new government structures introduced at the local level may contribute to the development of conflicts associated with REDD+ projects. (Alusiola et al., 2021; Awung & Merchant, 2020; Chomba et al., 2016; Lord, 2025; Nketiah et al., 2023; Poudyal et al., 2020; Satyal et al., 2020; Schmid, 2023; Soliev et al., 2021).

In this sense, conflicts associated with the implementation of REDD+ programmes, according to Mbatu and Eliamini (2025), can take on various scales, ranging from social-political structure conflicts, regional dynamics of REDD+ conflicts, and multi-level REDD+ conflicts.

Starting with regional levels of REDD+ conflicts, we can talk about conflicts that occur at the local level, between communities (mainly rural) that are heavily dependent on forest resources for their livelihoods, involving issues such as shared benefits, lack of community involvement in projects (e.g. in the Democratic Republic of Congo), or restrictions on access to forests (Cavanagh &

Benjaminsen, 2014; Mbatu & Eliamini, 2025; Samndong, 2018). Conflicts that occur at the national level and, as such, concern disputes between local communities and governmental policies, insofar as national policies and strategies for forest management can exacerbate local conflicts by reducing community access rights. On the other hand, these conflicts may also result from competition among national priority sectors, such as forest conservation, energy production, or agricultural expansion (Kemerink-Seyoum et al., 2018; Mbatu & Eliamini, 2025; Rahlao et al., 2012; Scheba & Rakotonarivo, 2016). Furthermore, although less common, conflicts that manifest in a transboundary manner cannot exclude the possibility of national interests from different States entering into a competitive dynamic (Cavanagh et al., 2015).

Accordingly to Mbatu and Eliamini (2025)

> due to economic interests, ecological concerns, and governance issues, the implementation of REDD+ initiatives in Africa has resulted in conflicts with a strong regional component, putting the interests of the local populace at odds with environmental preservation" (p.8), furthermore "in Central Africa, conflicts brought on by political instability have an impact on the implementation of REDD+. For instance, while implementing REDD+ projects, the Democratic Republic of the Congo lacks good governance because of conflicts (Mbatu e Eliamini, 2025, p.8).

Consequently, the implementation of REDD+ projects in Africa reveals the occurrence of multilevel conflicts, insofar as we can often observe the overlapping of various levels of conflict.

Finally, with regard to the socio-political structure of REDD+ conflicts, these are conflicts that encompass power dynamics, governance arrangements, community exclusion, the territorialization of state control, and the militarization of conservation. They therefore result from a combination of exclusionary practices, power imbalances, and unmet community expectations (Mbatu & Eliamini, 2025).

Now, this typology of conflict can be organized in another way, dividing conflicts into vertical and horizontal ones. The former refer to conflicts between different levels of actors and authority, which may occur between citizens/communities and the government, or between different levels of governmental administration. The latter refer to conflicts that arise from competing uses of the same resource – for example, between energy production and agriculture – as well as conflicts between non-state actors, such as different communities, or between state actors due to competing national interests. Thus, we can say that issues such as competition among national priority sectors, conflicting national interests, or competition between rural communities dependent on natural resources for their livelihoods constitute horizontal conflicts. Meanwhile, issues related to access restrictions or disputes between local communities and governmental policies may constitute vertical conflicts.

7. Final remarks

Africa's colonial past has left deep scars on its political systems, the legacy of various unresolved environmental and population crises, various political, social and ethnic conflicts, among others, are all factors that have contributed to deepening human insecurity and Africa's ecological crisis.

Africa's abundance of natural resources has the potential to promote regional development, yet in most cases there are lower levels of economic growth and development than in other regions with fewer resources.

In tropical Africa in particular, the tree is an important asset in the environmental system, not only because in general it contributes to the subsistence of life on the earth's surface, guaranteeing a vast regional biodiversity, but also because it contributes to the livelihoods of many households and is seen as an important economic asset.

However, human beings are avid predators of natural resources, feeding their evolution and industrialization through their exploitation and, in many cases, jeopardizing the fragile and important eco-sociological balance.

Climate change has profound impacts on ecosystems, and ecosystems, such as forests, have the potential to impact climate change, not least because of their role as a carbon dioxide sink. The accelerated deforestation taking place in several forests, some of them in tropical Africa, is jeopardizing this important function.

Consequently, a number of other risks arise from this, including the potential for a reduction in the presence of other natural resources, contributing to the deepening of a situation of human insecurity across several communities in tropical Africa.

The scarcity of natural resources as well as environmental degradation has the potential to lead to various types of disputes, and although "environmental wars" do not generally occur, this does not mean that communities with different priorities will clash over the control and exploitation of the same resources, or that different border states will not clash politically and diplomatically over cross-border resources.

Environmentally induced instability does not in itself trigger conflicts. Rather, it leads to an exacerbation of pre-existing local, regional or potentially international tensions, which can develop into a larger-scale conflict and eventually contribute to the degradation or total loss of the resource in question.

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José de Souza Larcher e o domínio inglês do Egipto nas *Impressões de Viagem* (1901)

José de Souza Larcher and British rule in Egypt in Impressões de Viagem (1901)

José das Candeias Sales
Susana Mota

Resumo

Em 1901, José de Souza Larcher (1821-1913) publicou o livro *Impressões de Viagem. O que eu vi e ouvi atravez do Egypto e da velha Europa*, em dois tomos, resultado de duas visitas ao Egipto (em 1894 e 1898), onde, entre muitos outros registos histórico-culturais, deixou também numerosos apontamentos sobre as tutelas britânica e otomana do Egipto. No presente texto procuramos explicitar os traços essenciais da visão e opinião de José de Souza Larcher, engenheiro, escritor e republicano, expectavelmente menos conhecido do que Eça de Queirós, sobre os grandes acontecimentos político-económico-militares de final do século XIX no Egipto.

Palavras-chave José de Souza Larcher, Egipto, século XIX, Literatura de viagens.

Abstract

In 1901, José de Souza Larcher (1821-1913) published the book *Impressões de Viagem. O que eu vi e ouvi atravez do Egypto e da velha Europa*, in two volumes, the result of two visits to Egypt (in 1894 and 1898), where, among many other historical and cultural accounts, he also left numerous observations on the British and Ottoman tutelage of Egypt. In this text we try to explain the essential features of the vision and opinion of José de Souza Larcher, an engineer, writer and republican, who is probably less well known than Eça de Queirós, on the great political-economic-military events of the late 19th century in Egypt.

Keywords: José de Souza Larcher, Egypt, 19th century, Travel literature.

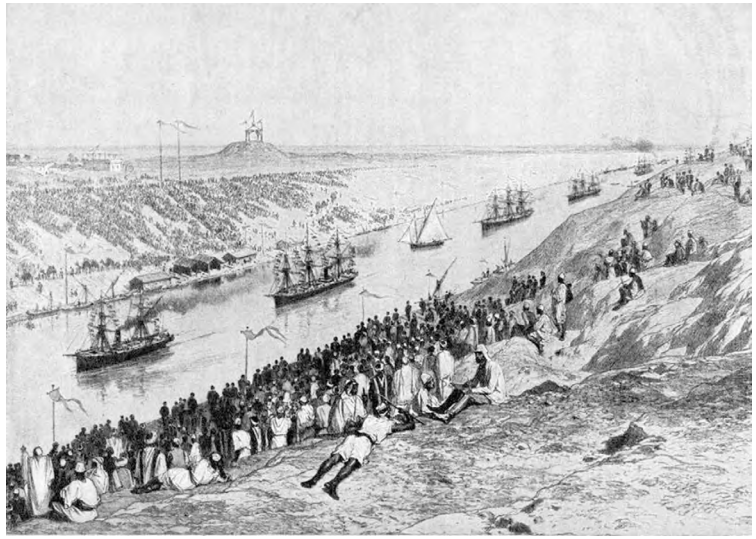
José das Candeias Sales
Universidade Aberta, Lisboa, Portugal
Centro de Estudos Globais da Universidade Aberta, Lisboa, Portugal
Susana Mota
Centro de Estudos Globais da Universidade Aberta, Lisboa, Portugal
0000-0003-1087-1478
0000-0002-4819-6239

Entre 27 de Setembro e 24 de Outubro de 1882, Eça de Queirós (1845-1900) publicou na *Gazeta de Notícias*, um dos mais influentes jornais do final do século XIX do Rio de Janeiro, seis textos jornalísticos intitulados "Cartas de Inglaterra - Os Inglezes no Egipto", editados postumamente, em 1905, em *Cartas de Inglaterra*, no Porto, pela Livraria Chardron de Lello & Irmãos - Editores (pp.125-205), onde, com um poderoso olhar crítico-reflexivo, comenta a cultura e os eventos políticos relevantes da Europa do seu tempo[1].

Como diplomata-cônsul, Eça de Queirós viveu 14 anos (entre 1874 e 1888) em Inglaterra (Newcastle e Bristol) e, a partir daí, foi enviando as suas impressões para o jornal brasileiro, elucidando os seus leitores sobre as relações entre a Inglaterra e o Egipto e sobre a história desse país sob o domínio otomano-britânico. Entre os seus comentários, em que verbera a brutalidade da exploração colonial britânica, aborda a destruição de Alexandria, em 1882, pela frota britânica no Mediterrâneo, e elogia o revoltoso nacionalista Arabi Pachá, que, contra os vários imperialismos em presença, reivindicava "o Egipto para os Egípcios – não para os empegados estrangeiros, nem para os agiotas estrangeiros…"[2].

Como Autor e como pessoa, Eça de Queirós valorizava o cosmopolitismo, a abertura ao mundo e as viagens. Como viajante, com apenas 23 anos, em 1869, a convite de D. Luís de Castro Pamplona, Conde de Resende (seu futuro cunhado), assistira no Egipto à abertura do Canal de Suez, sendo um dos poucos portugueses a assistir à inauguração de um dos maiores feitos de engenharia da época, desenvolvido sob a promoção francesa de Ferdinand de Lesseps. As suas impressões do Egipto dariam matéria para quatro crónicas ("De Port Said ao Suez") publicadas no *Diário de Notícias* (de 17 a 20 de Janeiro de 1870), para narrativas em *A Relíquia* (1887), publicada em vida, e para as póstumas *Cartas de Inglaterra* (1905) e *Egipto. Notas de Viagem* (1926), esta última compilada pelo filho, José Maria.

Na senda de numerosos autores de meados e do final do século XIX que fizeram do folhetim de viagens ao Oriente um popular género literário (como Robert Louis Stevenson, Benjamin Disraeli, Thackeray, Mark Twain, Gustave Flaubert, Théophile Gautier, Maxime du Camp, Gérard de Nerval, William Lane, Florence Nightingale, Ida Laura Pfeiffer, etc.), Eça de Queirós deixou vibrantes, coloridas e genuínas descrições da monumentalidade e do exotismo das gentes de Alexandria e do Cairo (Coelho, 2019).



Em 1901, José de Souza Larcher (1821-1913), pela mão de Mello d'Azevedo Editor, publicou, em Lisboa, o livro *Impressões de Viagem. O que eu vi e ouvi atravez do Egypto e da velha Europa*, em dois tomos, resultado de duas visitas ao Egipto (em 1894 e 1898), onde, entre muitos outros registos histórico-culturais, deixou também numerosos apontamentos sobre as tutelas britânica e otomana do Egipto.

Contemporâneos, Eça de Queirós e José de Souza Larcher viajaram ao Egipto, em momentos diferentes (aquele em 1869;

este em 1894 e 1898), e partilharam, assim, nas suas respectivas publicações, impressões e análises sobre a política internacional de finais do século XIX, tendo por centro o Egipto e em particular a cosmopolita Alexandria, que ambos visitaram, além de Port Said e do Cairo por onde também andaram[3]. Entre as suas viagens medeia apenas uma década e meia, embora entre a edição dos seus livros em Portugal existam apenas 4 anos de diferença, sendo, neste caso, o trabalho de Larcher (1901) anterior ao de Eça (1905).

No presente texto procuramos explicitar os traços essenciais da visão e opinião de José de Souza Larcher, engenheiro, escritor e republicano, expectavelmente menos conhecido do que Eça de Queirós, sobre os grandes acontecimentos político-económico-militares de final do século XIX no Egipto.

José de Souza Larcher e as *Impressões de Viagens* – enquadramento geral

Não existe ainda uma biografia devidamente elaborada sobre José de Souza Larcher, embora se consigam reconstituir, com relativa exactidão, vários aspectos fundamentais da sua existência, principalmente graças ao texto de Souza Quintella publicado, em 1883, na *Galeria Republicana*. Descendente da família Larcher instalada em Portalegre desde 1774, nasceu nessa cidade alentejana (5 de Maio de 1821), mudou-se para Lisboa, em 1834 (com 13 anos), para estudar, primeiro na Academia Real da Marinha e, depois, na Escola Polytechnica.

Alguns anos mais tarde, foi estudar em Paris na *École Centrale des Arts et Manufactures*, onde se formou em engenharia, regressando a Portalegre, em 1842 (com 21 anos), onde, após a morte do pai, em 1849, assumiu funções públicas e administrativas e de gestão na fábrica da família (no ramo dos lanifícios) e na agência do Banco de Portugal.

Já com 50 anos, em 1871, passa a dedicar-se em exclusivo à administração pública e à política, assumindo, em 1880, uma clara e oficial ligação ao Partido Republicano, como respeitado militante. Foi, de facto, um empenhado propagandista das ideias e dos ideais republicanos, designadamente no período que antecedeu a implantação do novo regime em Portugal, tendo sido, por exemplo, vereador no município de Lisboa entre 1893 e 1896. Faleceria a 3 de Janeiro de 1913, com 91 anos, pouco mais de dois anos depois de ser implantada a Primeira República Portuguesa, a 5 de Outubro de 1910[4].

A convite do seu filho mais novo, Alberto de Sousa Larcher (1848-1929), então juiz nos Tribunais Mistos do Egipto[5], José de Souza Larcher fez duas viagens ao Egipto: a primeira no início de 1894 e a segunda na primeira metade de 1898. Dessas viagens resultaram numerosas *impressões*, vistas e ouvidas, que recolheu, quer no território egípcio, então sob dominação otomana-inglesa, quer durante a viagem, nos vários pontos e escalas que teve de realizar, na ida e no regresso de cada uma das viagens. Foi o abundante material assim coligido que o levou a publicar, em 1901, o livro, em dois tomos, *Impressões de Viagem. O que vi e ouvi através do Egypto e da Velha Europa*.

Cada tomo é, como se destaca no frontispício, "Illustrado com numerosas e artísticas photogravuras". O primeiro, com 233 páginas, é composto por 17 Capítulos-Cartas[6] e ilustrado por 41 fotografias e desenhos, contendo o segundo, nas suas 248 páginas, mais 15 Capítulos-Cartas (da 18ª à 32ª) e 31 ilustrações.

Ao longo do I tomo, o Autor deixa repetidas alusões à presença e influência inglesa no Egipto, sendo os 4º a 8º Capítulos-Cartas os mais significativos neste aspecto, como mostraremos de seguida, e onde se congregam os seus principais pontos de vista sobre os vários episódios e características referentes ao protectorado britânico do Egipto.

Antes, à guisa de "declaração de interesse", logo na 1ª Capitulo-Carta, José de Souza Larcher esclarece os seus leitores do seu posicionamento no âmbito das relações egípcio-inglesas, fornecendo-lhes assim, *ab initio,* uma chave para o entendimento das suas considerações nos Capítulos-Cartas seguintes: ao mencionar o "bom Athias" (p.11), o drogman ou empregado-guia-intérprete que o tribunal misto de Port Said colocara ao seu dispor para o acompanhar por todo o lado, diz o engenheiro alentejano: "Eu tinha conquistado logo de principio a sua benevolência, declarando-me amigo dos arabes e grande adversário dos ingleses, e por isso, sempre que tinha ocasião me mostrava confiadamente o seu patriotico antagonismo contra os invasores da sua pátria" (pp.11-2).

De seguida, já na 2ª Capítulo-Carta, redige dois importantes parágrafos onde revela os seus processos de acesso à informação e ao conhecimento aprofundados sobre a história contemporânea do Egipto:

> Tivemos a fortuna de nos relacionar com o pessoal do tribunal mixto, composto além dos juízes europeus de juízes indígenas, formados em direito pela escola de Paris, e com vários advogados de diversas nacionalidades. Com uns e outros conversávamos em repetidas e largas conferencias sobre a actual situação do Egypto, os antecedentes que a determinaram, bem como sobre o ponto de vista religioso, e do organismo da sociedade civil estabelecido em harmonia com os preceitos exarados do Alcorão.
>
> De tudo o que colhi n'estas interessantes intrevistas, e pude observar e lêr sobre esses delicados assumptos; depois de bem degerido, combinado e fundido no meu pensamento, é que me foi possível constituir um fundo de informações que me habilitaram a formar uma opinião clara e segura sobre os factos ocorridos antes e depois da ocupação inglesa, dos quaes me proponho dar uma resumida descripção; bem como sobre outros assumptos importantes respectivos ao antigo e moderno Egypto, que não será a parte menos interessante da narrativa das minhas impressões, como viajante que procura vêr com interesse e zêlo, apreciando com desprevenido critério as coisas e as pessoas (pp.25-6).

O estimulante ambiente multicultural vivido entre os juízes do Tribunal Misto de Mansurah, em Port Said, permitira ao pai do juiz Alberto debates sobre os vários aspectos que conduziram à "actual situação do Egypto". No entanto, o pensamento crítico de Larcher não se forjara apenas nessas entrevistas:

> (…) no Oriente tudo é motivo de reparo e admiração para o viajante que pela primeira vez penetra n'aquelle novo velho mundo, e vae a cada passo vendo e ouvindo coisas, que, apezar das suas anteriores leituras sobre a historia antiga e moderna, lhe parecem de todo o ponto novas, inéditas, pela viva impressão que lhe produzem (p.6).

Às conversas intelectuais, Larcher acrescentará a observação pessoal, directa – "vendo e ouvindo" –, e leituras específicas sobre "o novo velho mundo" e os seus "delicados assumptos" da política (nacional e internacional) e da religião local[7]. Assim formou, diz ele, "uma opinião clara e segura sobre os factos ocorridos antes e depois da ocupação inglesa, dos quaes me proponho dar uma resumida descripção", ou seja, uma abalizada opinião, dizemos nós, conjugando vários informes, para partilhar com os seus leitores.

Ainda antes de descrever os factos inerentes à ocupação britânica, Larcher escreve no 3º Capítulo-Carta:

> A ultima revolução nacional que houve no Egypto, contra a influencia e imposições dos europeus sobre o governo do paiz, teve a sua origem nas sociedades secretas do Cairo, que excitando o sentimento religioso e attrahindo a si o elemento militar, conseguiram elevar um dos seus adeptos, o infeliz coronel Arabi, ás eminencias do poder como ministro da Guerra.
>
> Este apelo ao fanatismo, que tão rapidamente foi segundado por todo o Egypto, prova bem a força da organização d'aquellas mysteriosas associações, e a gravidade dos acontecimentos que podem advir da sua acção, quando sejam dirigidas por homens de altas faculdades e competência. (p.39).

Esta referência à "ultima revolução nacional" e ao político, militar e revolucionário egípcio Arabi (1841-1911), também chamado Ahmed Urabi ou Ahmed Arabi al-Husayni – que Eça de Queirós também, menciona[8] –, significa que tinha perfeita noção do seu papel, intervenção e impacto no desenrolar da situação de política interna e externa egípcia do seu tempo, como demonstrará cabalmente na 4º Capítulo-Carta.

O protectorado britânico: antecedentes

Este Capítulo-Carta é realmente decisivo para traçar os antecedentes da invasão inglesa ou, como ele escreve a iniciá-lo: "fazer uma breve apreciação do protectorado inglez, historiando rapidamente as causas que determinaram o importante facto da intervenção da Inglaterra, e justificam até certo ponto a sua demorada permanência no valle do Nilo." (p.45).

Para a sua panorâmica histórica, recua até aos anos 60 do século XIX – a época em que Eça de Queirós estivera no Egipto –, dividindo-a de acordo com os mandatos do avô e pai do jovem Khediva Abbas Hilmy II (1874-1944, vice-rei: 1892 e 1914) que se encontrava no poder aquando das suas duas visitas ao Egipto, ou seja, os Khedivas Ismail Pachá e Taufik Pachá respectivamente, que foram "vice-reis do Egipto e do Sudão" de 1863 a 1879 e de 1879 a 1892 (Sales, 2024; Mansfield, 2003, pp.105-6)[9].

Sobre a acção político-económica-financeira de Ismail Pachá, J. S. Larcher escreve:

> O genio audaz, o coração generoso e uma paixão desordenada por todas as manifestações do luxo e do progresso, são os traços principaes da grande figura do já falecido Khediva Ismail, avô do actual soberano do Egypto. Durante o seu governo o estudo das sciencias teve notavel desenvolvimento; estabeleceu escolas de direito, de medicina, de engenheria; mas sobre tudo o que sempre mais captivou a atenção, foram as obras publicas, a construção de canaes, pontes, teatros, palacios e jardins. O Cairo foi transformado e ampliado, e novos bairros se levantaram em nada inferiores aos boulevards tão elogiados do barão Haussmam, em Paris. (I tomo, 4ª Carta, pp.45-6).

A informação transmitida acentua o desenvolvimento e a modernização do país incrementados pelo Khediva Ismail, sem deixar de frisar a sua "paixão desordenada por todas as manifestações do luxo e do progresso", razão para a qual, no fundo, pretende remeter a conclusão que as páginas seguintes apresentarão. Significa isto que Larcher reconhece os impulsos positivos que o Egipto conhecera sob o governo deste vice-rei e a que confere relativo desenvolvimento nos parágrafos seguintes:

> O grande impulso que se deu para a construção da famosa ponte barrage sobre o Nilo, a elle se deve, e tudo o que se fez, com uma pompa verdadeiramente oriental, para celebrar a inauguração do Canal de Suez, excedeu o que na Europa é costume fazer-se nas grandes festas internacionais.
>
> Mandou construir um soberbo palácio junto ás margens do canal, e outro mais explendido na ilha Guizereth, – Cairo – para receber os seus augustos hospedes, correndo por sua conta a despeza do sumptuoso serviço e dos transportes terrestres e fluviais através do Egypto, até ás primeiras cataractas. Abriram-se estradas novas para o facil acesso ás pyramides, desenterraram-se monumentos grandiosos dos tempos faraónicos, que havia muitos seculos jaziam ocultos debaixo de montões de arêa, e que n'essa ocasião puderam patentear aos olhos maravilhados dos nobres visitantes a sua gigantesca structura e as preciosidades artísticas encontradas no seu interior.
>
> Na Opera do Cairo deram a primeira representação da Aida com o luxo oriental, realçado pela apropriada côr local, e desempenhada pelos mais celebres artistas europeus. Em seguida a tantas festas deslumbrantes, na ocasião das despedidas, Ismail, ainda julgou não ter feito bastante para mostrar o seu reconhecimento pela honrosa visita de tão ilustres personagens, e para não ficar com escrúpulos de ter deixado de fazer alguma coisa que poderia esperar-se da sua bizarria, presenteou todas as princesas e damas de alto cothurno com joias da mais rica pedraria. (pp.46-8).

A linha explicativa que José de Souza Larcher apresenta aos seus leitores faz derivar destas pomposas e dispendiosas "decisões governativas" em torno da construção e da inauguração do Canal de Suez todas as dificuldades que levariam à queda definitiva de Ismail do poder em 1879, sob pressão britânica e francesa[10].

Ismail Pachá ficou, realmente, associado a uma série de reformas na agricultura, na indústria, no comércio e na educação, mas não resistiu ao excesso de empréstimos contraídos para a suportar e à correspondente bancarrota egípcia em 1876, ainda mais profunda do que a que atingira, meses antes, a Turquia (Daly, 1998, p.239-40; Mansfield, 2003, p.89; Troutt Powell, 2003, p.67). A ele se deve, em 1876, como já mencionámos, o estabelecimento dos Tribunais Mistos, cujo funcionamento, no fundo, pela presença do filho, está na origem das visitas de José de Souza Larcher ao Egipto e, em consequência, das suas "impressões" (Cleveland, Bunton, 2009, p.96).

A dispendiosa guerra com a Etiópia, sobretudo a partir de 1872, com vista a unificar o vale do Egipto e criar uma província egípcia no Sudão, agravou ainda mais a situação de debilidade económico-financeira do Egipto, de enorme repúdio da população egípcia e de avidez dos financiadores ingleses e franceses. Há dados que estimam que quando assumiu o poder (1863), a dívida nacional egípcia era de cerca de 3.000.000 £; em pouco mais de 10 anos (1876), essa dívida havia aumentado para quase 100.000.000 £ (Cleveland, Bunton, 2009, p.99; Mcilwraith, 1917, p.248).

A severa dívida pública resultante dos sucessivos empréstimos contraídos por Ismail Pachá, levou à venda de 44% das acções do Egipto na Companhia do Canal de Suez a favor do governo britânico (na altura dirigido por Benjamim Disraeli) e conduziu irremediavelmente o país para a esfera de dependência das potências europeias de quem o Khediva (educado em Paris) tanto tinha tentado aproximar-se (Troutt Powell, 2003, p.67; Mansfield, 2003, p.88-9). Em consequência, o Egipto não tinha qualquer direito aos lucros do Canal, pois eles pertenciam apenas aos britânicos e aos franceses. O "grande gastador" caía sob a "tutella" dos seus credores. O Egipto afundava-se em dívidas e perdia a sua autonomia política:

> Depois d'esta quadra brilhante e de se terem gasto rios de dinheiro, recorrendo-se aos emprestimos; quando o pobre fellah já nada mais tinha para entregar aos agentes do fisco, começou rapida a decadencia do Egypto, que se anunciou temerosa, quando não foi possivel contrahir novos emprestimos, e não haver receita para pagar os juros da divida publica.
>
> Chegado o Khediva a tão apertadas circumstancias teve que sujeitar-se á imposição de uma commissão estrangeira – franceza e inglesa – que teve por incumbencia apoderar-se da receita das alfandegas e de outros serviços financeiros que foram julgados necessários para garantirem o regular pagamento dos juros da divida.
>
> O primeiro resultado da ingerência da commissão nos negócios financeiros do Egypto foi a redução a muito estrictos limites das despezas do Khediva. Para o grande gastador era esta situação insuportavel, e naturalmente o incitava a procurar todos os meios de evitar tão desagradável tutella.
>
> Mas a sua falta absoluta de recursos, e a acção diplomatica das grandes potencias, não permittiam que as suas tentativas de independencia podessem produzir um resultado favoravel aos seus planos, e bem longe d'isso só serviam para irritar os animos e agravar a sua situação.
>
> E de feito não tardou que as potencias, já cançadas de tanta resistencia, e perdida a esperança de obterem de Ismail completa submissão, recorressem a meios mais inergicos, e sem mais detença propozeram e obtiveram da Sublime Porta a deposição do Khediva, seu vassalo, e o consequente exilio para longe das margens do Nilo (pp.48-9).

A "Comissão" a que Larcher faz alusão (*Caisse de la Dette Publique*) era composta por quatro representantes das nações

credoras europeias e estava encarregue de garantir que a dívida egípcia fosse paga. Além disso, dois controladores, um da Grã-Bretanha e outro da França, foram nomeados pelo governo egípcio para supervisionar os gastos das receitas egípcias (Cleveland, Bunton, 2009, p.99).

O resultado concreto da actuação deste duplo controlo, além de aumentar os impostos e taxas pagas pelos *fellahin*, foi atribuir o controle total das finanças egípcias aos credores europeus do Egipto, ou seja, privou o Egipto de qualquer traço de independência (Reid, 1998, p.219; Mansfield, 2003, p.89). Ademais, os governos da Grã-Bretanha e da França, encorajados pela Alemanha e Áustria, forçaram finalmente o Sultão otomano a depor Ismaïl em 1879 e a instalar no poder o seu filho Taufik, como novo khediva (Troutt Powell, 2003, p.67).

Desde 1841 (Édito de Herança) que o Egipto beneficiava do estatuto de província privilegiada dentro do Império Otomano, pagando um tributo anual, e que tinha assegurada a sucessão hereditária do seu governo para a família de Mehemet-Ali (Oded, 2005, p.103; Fahmy 1998, pp.139, 178-9; Mcilwraith, 1917, pp.244-5). Em 1867, através de um *firman* imperial, o Sultão Abdulaziz, segundo rumores primo de Ismail (as suas mães seriam irmãs), muda o estatuto do Egipto otomano de "província" (*eyalet*) para "khedivato" (*hidiviyet*), o que significa que o título passava a ser hereditário (Mestyan, 2017, pp.3, 50; Mcilwraith, 1917, pp.244, 246; Mansfield, 2003, p.88; Hunter, 1999, p.190). Assim, com esta "independência" e "senioridade" garantida, Ismail foi sucedido pelo seu filho Taufik Pachá (1852-1892), que se revelaria pouco mais do que um fantoche na mão dos ingleses:

> Foi Tewkik, filho mais velho do principe desthronado, que lhe sucedeu no governo do Egypto. O novo Khediva não tinha o caracter apaixonado e o genio audaz de seu pae; não sabia resistir, nem sequer o tentava, e as exigências da commissão fiscal para se reduzir o orçamento a modestos limites, compatíveis com a estreiteza dos recursos, foram sempre acatadas sem o mais leve reparo. (p.49)[11].

A posição de fragilidade e dependência face às exigências financeiras das potências europeias em que Taufik chegara ao poder é claramente enunciada por Larcher. A margem de acção do novo vice-rei era muito reduzida. Ao tentar, ainda assim, intervir na redução das despesas, fê-lo num sector da sociedade egípcia que se revelaria contraproducente para as suas ambições: o exército nacional:

> Uma das reducções de mais importância que se operou na despeza, foi a do licenceamento de parte do exercito; mas esta medida não podia passar sem ferir muitos interesses; o descontentamento foi profundo e geral entre a oficialidade, e d'esta se foi propagando pela classe civil, com uma feição especial de sentimento religioso, inseparavel de todas as questões que no Oriente se levantam entre christãos e os filhos do Propheta.(p.49).

Foram compulsivamente aposentados 1.600 oficiais do exército (de um total de 36.000) e o salário dos restantes membros foi reduzido para metade (Reid, 1998, 220; Lutzky, 1969, 203). É neste contexto que surge Ahmed Arabi, o coronel egípcio a que Larcher já fizera antes referência e que volta agora a mencionar:

> O coronel Arabi, que desprovido de instrucção, e só pelo prestigio do seu natural talento, boa presença e grande facilidade de falar com calor e elegância, soube conquistar grande popularidade ao Cairo, sobretudo entre o elemento militar, que elle chegou a dominar por completo, a ponto de se impor ao irresoluto Khediva e obter d'elle a formação de um ministério do qual foi chefe e ministro da guerra. (pp.49-50).

O militar egípcio que, em 1879, fundara o Partido Nacional (*Hizb al-Watani*) e que pretendia expulsar britânicos, franceses e turcos do Egipto, com o aumento da sua popularidade foi realmente nomeado como ministro da Guerra pelo Khediva Taufik, em 1881 (Cleveland, Bunton, 2009, p.100; Troutt

Powell, 2003, p.68). Apesar da menção de Larcher à falta de instrução de Arabi ser menos correcta, uma vez que, embora sendo de origem humilde, como *fellah*, teve instrução primeiro na Universidade de al-Azhar e depois, como oficial do exército, foi ele que instigou e liderou a insurreição popular dos *waitinum* ("nacionalistas") contra os habitantes europeus de Alexandria, com o *slogan* "O Egipto para os Egípcios", sublinhando a vertente proto-nacionalista do movimento, e que lhe granjeou reconhecimento como "cabeça e campeão do Islão" (Reid, 1998, p.218; Cleveland, Bunton, 2009, p.99).

De facto, foi a chamada "Revolta de Arabi" (*asilik*), entre 1879 e 1882, contra o Khediva Taufik Pachá, contra o monopólio dos altos postos militares pelos turcos e contra a crescente dominação europeia (anglo-francesa) do Egipto que levou à invasão do Reino Unido, a pedido de Taufik, e ao estabelecimento da ocupação britânica que se estenderia por 40 anos, até 1922 (Reid, 1998, p.217; Cole, 1995).

Identificado por Larcher como homem de "altas faculdades e competência" (p.39), Arabi está realmente ligado, na sua percepção histórica de 1894/1898, à "ultima revolução nacional que houve no Egypto, contra a influencia e imposições dos europeus sobre o governo do paiz" (p.39). A história mostraria depois, ao longo dos anos, o eclodir de uma série de outras revoluções que fazem com que o movimento de Arabi seja, antes, uma das primeiras revoluções liberais-nacionais orientais contra o controle europeu. Larcher conhecia e compreendia bem os eventos político-militares subjacentes ao início da ocupação britânica do Egipto e transmitia-os, através dos seus personagens mais destacados, aos seus leitores, conjugando as suas dimensões de político e de escritor.

Linha superior, da esquerda para a direita: o Khediva Ismail Pachá; o Khediva Taufik Pachá; o Khediva Abbas Hilmy II. Linha inferior: Arabi Pachá (1841-1911). © Domínio Público.

O protectorado britânico: detonação - o bombardeamento de Alexandria

Quando, ainda na 4° Capítulo-Carta, alude à crise egípcia que marcaria o período de Setembro de 1881 a Setembro de 1882 e acrescenta na sua narrativa dos acontecimentos:

> Depois d'este facto que mostrou aos egypcios a importancia de Arabi, a corrente da opinião manifestou-se abertamente contra todos os estrangeiros; as ameaças e as invectivas foram tomando vulto, e a audacia do povo fanatizado subiu de ponto na presença da attitude do Khediva, sempre timorato, irresoluto, não se pondo claramente á testa do movimento, nem pedindo auxilio ao Sultão para dominar a situação critica em que se via.
>
> N'esta triste conjunctura a colonia europeia começou a ter sérios receios de saque e de morticínio, e para se subtrahir a perigo tão iminente, emquanto era tempo, resolveu abandonar o Egypto (p.50).

O nosso autor está a preparar o desenlace para os eventos que, na sua narrativa e na história, foram fundamentais, a saber, o bombardeamento e destruição de Alexandria (11-13 de Julho de 1882), pela frota de 15 couraçados da Royal Navy, sob o comando do Almirante Frederick Beauchamp Seymour, e o estabelecimento do protetorado inglês sobre o Egipto[12]. Enfaticamente, o seu relato prossegue:

> Enquanto estes sucessos se desenrolavam, a diplomacia não ficava de braços cruzados; fizeram-se altas diligencias para uma acção comum, e com esse intuito os representantes das potencias celebraram longas conferencias, por vezes interrompidas pela dificuldade de chegar a um acordo e de conciliar todos os interesses em jogo.
>
> Afinal a Inglaterra, a França e a Itália tomaram a resolução de enviar para o porto de Alexandria as suas esquadras, sem plano preconcebido do uso que deveriam fazer d'aquella imponente reunião de grandes vasos de guerra.
>
> Logo que no Egypto houve conhecimento da chegada das esquadras a efervescência foi enorme, e não faltaram actos de violência nos grandes centros do Cairo e de Alexandria. (…)
>
> As esquadras da França e da Italia não quiseram tomar parte nas demonstrações bellicas que a gravidade da situação exigia; afastaram-se do porto, deixando á esquadra inglesa completa liberdade de acção e a responsabilidade dos sucessos futuros, de um alcance enorme, e ainda de natureza desconhecida, no momento em que as hostilidades iam começar.
>
> O almirante Ingles não teve hesitações; o bombardeamento começou sem demora, e não tardou que os fortes que defendiam a cidade fossem desmantelados e dispersas as forças que os guarneciam. (pp.50-1).

As grandes potências da época (Grã-Bretanha, França, Rússia, Alemanha, Áustria e Itália) reuniram-se em Constantinopla (Conferência de Constantinopla) e, nesse mesmo ano, formou-se a tríplice aliança militar (Alemanha, Itália e Áustria). A acção diplomática tentou, em vão, impedir a invasão britânica.

O próprio Império Otomano, perante a delicada "Questão Egípcia", face ao desenrolar dos acontecimentos num território que estava nominalmente sob a sua suserania e que conhecia uma rebelião encabeçada por Arabi, foi convocado a assumir várias posições, globalmente tendentes, no fundo, à preservação do império, suportando Taufik Pachá como legítimo governante do Egipto e representante do Sultanato, e contrárias a qualquer intervenção naval estrangeira no Egipto (Deringil, 1988).

Depois da "franca exposição das causas que determinaram a intervenção da Inglaterra no governo do Egypto" (I tomo, 8ª Carta, p.85), em várias outras passagens na 8° Capítulo-Carta percebe-se o tom de perplexidade e incompreensão do Autor perante a desproporcionalidade dos meios usados pela Inglaterra para combater os movimentos nacionalistas de Arabi:

> Parece-nos também conveniente, para imprimirmos á nossa narrativa um caracter de uma completa imparcialidade, não deixar de analysar á luz de uma serena e desapaixonada critica, se os meios empregados para com seguir a victoria foram exactamete proporcionaes ás necessidades da lucta.
>
> N'este ponto, triste é confessal-o, o governo inglez foi muito além dos limites que uma nação civilisada nunca deveria ultrapassar. Praticar actos de feroz crueldade, desnecessários para garantir a propria segurança, completamente injustificáveis perante as mais evidentes exigencias da situação que se pretendia dominar, é esquecer todo o progresso que a civilisação tem introduzido nas leis da guerra, procurando restringir os seus deploraveis efeitos só aos males absolutamente inevitáveis.
>
> É retrogradar aos tempos barbaros do maior absolutismo e ferocidade, quando o vencedor passava a fio da espada populações inteiras, queimando, assolando e destruindo tudo, e apoderando-se dos territórios como feudo e dos superviventes como escravos. (I tomo, 8ª Carta, pp.85-6).

Neste contexto, é inevitável e clara condenação do escritor português do bombardeamento de Alexandria pela frota britânica do Mediterrâneo[13]:

> O bombardeamento de Alexandria foi um acto altamente condemnado a todos os respeitos, e será para a historia da Inglaterra uma nodoa indelevel, (…).
>
> N'estes tristissimos successos a Inglaterra só attendeu ao effeito político da sua atrocidade, querendo deixar bem impresso no cerebro dos habitantes das nações vencidas a idéa sinistra da sua implacavel força, para que este sentimento de terror se propagasse de geração em geração, afim de nunca mais lhe contrariarem as pretenções, ou terem velleidades de sacudir o seu pesado jugo. (I tomo, 8ª Carta, p.86).

Numa profunda e sempre actual reflexão sobre as consequências da violência desmedida a curto, médio e longo prazo, José de Souza Larcher acrescenta:

> É inegável que se tal processo infunde submisso respeito por um adversário que nada respeita, não deixa por outro lado de cimentar entre as victimas da prepotência, os mais vivos sentimentos de odio e rancor, que nem os seculos conseguem apagar, ficando indefinidamente de reserva para o futuro dia das reivindicações possíveis. (I tomo, 8ª Carta, pp.86-7).

A descrição narrativa de Larcher é pontuada por outras interpelantes questões:

> Desmoronados os fortes e destruída a artilheria que os guarnecia; dispersas as tropas egypcias que procuraram em seguida sahir apressadamente d' Alexandria para irem reunir-se ao grosso do exercito; restavam apenas na cidade alguns centos de maltrapilhos de varias raças e população indigena (…).
>
> Para que, n'estas condições bombardear a cidade? Que culpam tinham as famílias europêas, coptas e turcas que ali residiam (…) da pretensão de Arabi querer rebellir o ataque da esquadra inglesa?
>
> E além d'isso, por que, depois de bombardeada a cidade durante dois dias, não se fez desembarcar tropa para impedir que os ladrões aproveitando-se da desordem, do terror e da fuga dos habitantes, continuassem a roubar e incendiar; permitindo assim que durante 48 horas Alexandria estivesse á mercê dos malfeitores? (p.91).

Mesmo conhecendo a relativa, mas assumida animosidade de Larcher contra a acção dos ingleses no Egipto, isso não toldou a sua nítida identificação das respostas às perguntas que retoricamente colocava ou, se quisermos, da justificação para o massacre infligido pela frota inglesa:

> (…) da parte dos inglezes havia um grande interesse que os impellia a tão monstruosa resolução, além do terror, em que a sua tortuosa politica se firma, para avassallar os animos, e mais facilmente conseguir os seus fins de engrandecimento e dominio sem limites.
>
> Era a questão commercial, que se erguia imponente, a grande instigadora do bombardeamento. Reduzir uma grande cidade a um montão de ruinas, deixar consumir pelas chammas e pela rapina grandes e valiosissimos depositos de mercadorias, arruinando o commercio de nacionalidades rivaes; para em seguida recompôr tudo com engenheiros e artistas inglezes, e com uma verdadeira inundação de mercadorias procedentes d'Inglaterra, que, por via de regra, não pagavam direitos d'entrada, sob o falaz pretexto de serem destinadas ao fornecimento do exercito que tinha vindo libertar o Egypto das loucuras de Arabi; foi, como toda a gente o reconhecerá, a operação mais bem combinada e de mais brilhantes resultados, que o espirito mercantil dos negociantes de Londres e Manchester podiam inspirar ao seu illustrado governo (p.92).

De forma racional e esclarecida, Larcher vai ao fulcro do problema: "Era a questão commercial, que se erguia imponente, a grande instigadora do bombardeamento". (p.92). Para ele, Inglaterra queria principalmente "procurar novos mercados onde se consumam os tecidos de Leeds e de Manchester, e muitos outros artefactos e productos da potente industria inglesa. Esta nação bem sabe que sem commercio externo não póde existir" (I tomo, 8ª Carta, pp.88-9); "Cessando o commercio, fecham-se as fabricas" (I tomo, 8ª Carta, p.90).

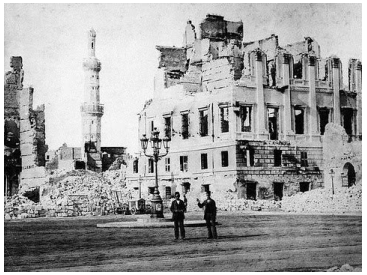
Embora não apareçam suficientemente explicitados por Larcher e se possam confundir, numa primeira leitura, com uma resposta repressiva às insurreições nacionalistas e xenófobas egípcias

na cidade, os objetivos do bombardeamento de Alexandria prendiam-se com a defesa do império britânico através da protecção da rota do Suez, o mesmo é dizer com a segurança do tráfego marítimo que alcançava através do Canal, vital para as suas ligações com a colónia na Índia (Cleveland, Bunton, 2009, p.104; Chamberlain, 1977).

O bombardeamento foi apresentado pela Inglaterra como um acto de auto-defesa. É exemplar, contudo, a forma como, sucinta, mas objetivamente, Larcher cria um cenário de explicação para a prepotente política externa inglesa e para os termos despóticos, dominadores, exploradores e verdadeiramente imperialistas adoptados pela Inglaterra, facilmente entendíveis por um leitor medianamente interessado:

> A Inglaterra é um colosso, mas as exigências da sua existência económica impellem-n'a a dilatar-se com uma tenacidade incrível, cega, que nada respeita, verdadeira lucta pela vida, esquecendo que pouco segura quem muito abarca. A sua grandeza é a sua fraqueza; desenvolvimento anormal, estado agudo de plethora colonial. Assim como a grande nau se apoia no fluido elemento sempre incerto e movediço, assim a Inglaterra se firma no mar instavel de contingências ameaçadoras; uma e outra sempre expostas a ocultos baixios e a imprevistos cyclones. Sem exagerada hyperbole póde dizer-se: o colosso tem pés de barro. (I tomo, 8ª Carta, p.90).

Navios britânicos bombardeando Alexandria, em 1882. © Domínio Público.



Fotos de Alexandria depois do bombardeamento e incêndio de 11–13 de Julho de 1882. © Domínio Público.

Na 24ª Carta, já no II tomo, onde traça um panorama histórico geral da cidade, desde a Antiguidade até aos seus dias, com destaque para as acções de Alexandre Magno, dos Ptolomeus, dos Césares, de Napoleão Bonaparte e de Mehemet-Ali (pp.101-6), a temática do bombardeamento de Alexandria é retomada por Larcher: "Alexandria soffreu muito com o bombardeamento, moral e materialmente, ficando arrasada em parte e a sua população dispersa, os indígenas fugindo para o interior e muitos milhares de europeus embarcando para os seus respectivos paizes" (p.106).

Na sequência desta referência, uma vez mais sensível ao diálogo entre o histórico lido e o histórico vivenciado, o nosso Autor deixa a seguinte observação:

> "(…) no fim de três anos, ainda antes de pagas as indemnizações, já era grande o número das reedificações; continuando as obras, depois de indemnizados os prejuízos, com febril actividade; a ponto que em 1894, quando visitámos Alexandria pela primeira vez, já a encontrámos restaurada e mais bella do que era anos antes." (p.107).

A dúzia de anos passada, com uma série de indemnizações pagas às "nações cujos súbditos tinham sido victimas do bombardemento" (I tomo, 8ª Carta, p.92), "fazendo recahir esse pesado encargo sobre o pobre paiz conquistado" (I tomo, 8ª Carta, p.93) e fazendo "o levantamento de um empréstimo em nome do Egypto e garantido pelo governo britannico a fim de liquidar essa delicada questão" (I tomo, 8ª Carta, p.93), parecia ter apagado os sinais da catástrofe e dos tristes dias vividos pela cidade ("Começou então Alexandria a ressurgir das próprias ruinas" - I tomo, 8ª Carta, p.94).

No entanto, os interesses ingleses continuavam a fazer-se sentir de forma muito intensa, numa época em que se vivia o primeiro período do domínio *britânico* (1882-1922), muitas vezes chamado de "protectorado" ou de "*protectorado* velado" (1882-1914) – em vigor nas duas ocasiões em que Larcher esteve no Egipto –, em que o Egipto continuava legalmente uma província autónoma do Império Otomano, mas sob um protectorado informal, *de facto,* inglês (Daly, 1998, p.245-6; Cleveland, Bunton, 2009, p.104).

Com o eclodir da I Guerra Mundial, o Império Otomano juntou-se às Potências Centrais, apoiando a Alemanha (Novembro de 1914), ao que a Inglaterra respondeu, com vista à preservação do seu domínio sobre o Canal de Suez, com a declaração unilateral do seu protectorado sobre o Egipto *de iure*, iniciando o que se designa por "protectorado formal", que se estenderia de 1914 até à independência formal do Egipto, a 28 de fevereiro de 1922, com novos movimentos nacionalistas, agora congregados em torno do Partido Wafd (em árabe, *Hizb al-Wafd*) e do seu líder Zaghloul-pachá (1859-1927), também conhecido como Saad Zaghloul, que naturalmente José de Souza Larcher já não acompanharia, pois faleceria em 1913 (Mcilwraith, 1917; Janikowski, 1988; Gershoni, Janikowski, 1986; Daly, 1988, pp.248-50; Botam, 1988, pp.287-8).

Mesmo depois de 1922, com a "monarquia colaboracionista" de Ahmed Fuad I, a Inglaterra continuou, todavia, a dominar a vida política do Egipto, controlando a zona do Canal de Suez, o Sudão e a política externa egípcia e com uma presença militar regular que permitiria usar o país como base de operações aliadas em toda a região durante a II Guerra Mundial (Botam, 1988, p.285). Essa presença militar só seria eliminada efectivamente com a Revolução Egípcia de 1952 e com todos os episódios de nacionalismo, pan-arabismo e autonomia que a antecederam e que lhe sucederam (designadamente a nacionalização dos proventos económicos do Canal do Suez, em 1956, já com Gamal Abdel Nasser como Presidente da República Árabe do Egipto: "O Canal é nosso e só nosso").

O bombardeamento de Alexandria de Julho de 1882 não encerrou as hostilidades inglesas contra os Egípcios, como José de Souza Larcher fizera questão de mencionar:

> Logo depois effectuou-se o desembarque das tropas de combate para fazerem cessar todos os malefícios de feroz vandalismo que enlutavam a nobre cidade, e prosseguir seguidamente na empresa que então parecia arriscada, de bater o exercito egypcio comandado pelo ministro da guerra, Arabi, e que este tinha reforçado com tribus de beduinos, e tudo concentrado no lado oriental do Delta, a pequena distancia do Canal de Suez.
>
> Os inimigos avistaram-se, tomaram posições em Tel el Kebir, e tudo fazia presumir que no dia seguinte haveria em torno d'aquella pouco elevada colina um importante e sangrento conflicto. Mas durante a noite o general inglez, Wolseley, recorrendo á mais potente e eficaz arma de guerra que a Inglaterra possue, inutilizou por completo o exercito egypcio. (I tomo, 4ª Carta, pp.51-2).

Já na p. 12 (1° Capítulo-Carta), quando se referira ao drogman Athias, J.S. Larcher escrevera:

> No trajecto que se percorria, passamos pelo sitio Tell-el-Kebir, onde se deu a celebre batalha em que as libras, mais do que os cartuchos inglezes, dispersaram as tropas do exercito egypcio, já reduzidas, na ocasião do combate, a um pequeno corpo que tinha permanecido fiel a Arabi, o chefe infeliz do partido nacional.

Ao passar pelo local, portanto, a 75 Km a sul de Port Said, onde ocorrera, a 13 de Setembro de 1882, a Batalha de Tell el-Kebir, Larcher demonstra saber que a mesma fora travada entre o destroçado exército egípcio liderado por Ahmed Arabi e as forças armadas britânicas de Garnet Wolseley e que representara o fim da rebelião de Arabi. As conversas, a observação no terreno, vendo e ouvindo, e as suas leituras provaram ser bem ajustadas à sua análise da conjuntura egípcia em torno de 1882.

O valor das "libras" volta a ser por ele mencionado na p.52:

> Os beduinos astutamente subornados tinham desaparecido, e com eles muitos dos príncipaes chefes das tropas regulares, junto dos quaes tambem se invocou o nome do Sultão, por forma que ao toque d'alvorada o infeliz Arabi apenas se viu rodeado de poucos adeptos, e quasi sem resistência foi destroçado e preso.
>
> Assim acabou a revolução do Egypto contra a ingerência dos europeus nos seus negócios cazeiros. Á Inglaterra se deve o prompto desenlace do drama, que poderia ter sido muito diverso, se o poder do oiro não fosse tão seductor, mesmo em frente do sentimento patriótico e religioso de raças diversas e pouco amigas[14].

O protectorado britânico: consumação - a Batalha de Tell el-Kebir

A Batalha de Tell el-Kebir representou a consumação da vitória inglesa e a verdadeira capitulação das pretensões revolucionárias nacionalistas de Arabi e dos seus homens e, em consequência, assinalou, de facto, o domínio inglês. O escritor alentejano, no 5° Capítulo-Carta fornece essa perspectiva aos seus leitores:

> Consumada a vitoria, a Inglaterra, a quem a Europa abandonou o encargo de restabelecer a ordem no Egypto, sem se importar com os riscos nem com as vantagens resultantes da empresa; a Inglaterra, tão enaltecida por um exito tão rápido como problemático, tomou posse do paiz com mão firme e processos ilustrados; tendo em mira principalmente, como era de esperar, os seus intentos políticos e commerciaes, sem se impressionar muito com as reclamações das grandes potencias, que desde então lamentam platonicamente a prolongação do indeterminado protectorado inglez. (p.53).

Sem hesitações, Larcher emite a sua "humilde opinião" (p. 53): o abandono das esquadras da França e da Itália do porto de Alexandria foi um acto consciente, "em troca das vantagens que a Inglaterra devia tirar do Egypto, a Italia obteve o appoio da influencia inglesa para as suas empresas africanas, o sonhado protectorado na Aybssinia [sic], e a França a tolerancia indispensável para se estabelecer sem reclamações embaraçosas em Tunis e no Touquim" (pp.53-4). Dando prova de uma enorme capacidade de interpretação dos eventos e da sua repercussão na geo-estratégia internacional da época, o nosso Autor não vê contradições no desenrolar dos acontecimentos, mas, antes,

"convenções secretas" e a "trama dos valores entendidos" das potências europeias com interesses em várias regiões de África. Só os "ingénuos ou indiferentes" não descortinavam os "machiavelicos ardis" da diplomacia europeia, unida na defesa dos seus diversos interesses coloniais.

A leitura do engenheiro português é também muito acurada quando analisa a própria estrutura de dominação inglesa no Egipto, que reputa de sagaz e hábil. São cinco parágrafos que constituem uma autêntica lição teórico-prática sobre as relações internacionais, certamente muito esclarecedora para a maioria dos seus leitores:

> A Inglaterra conquistou na realidade o Egypto, mas em logar de desthronar o imperante e de impor-se abertamente como amo e senhor absoluto, como o faria qualquer vulgar conquistador, só atendeu ao positivo das coisas e não a vãs apparencias. O Khediva continuou a exercer as suas funções de chefe de Estado e a governar o Egypto por meio dos seus ministros e agentes.
>
> N'isto se revela a sagacidade e rara habilidade do governo inglez: não fere insolentemente as susceptibilidades nacionaes, apresenta--se apenas como conselheiro amigo e devotado protector, e com estes fundamentos tão nobres e sympathicos, foi colocando junto de cada ministro, e á testa de todas as administrações publicas, agentes ingleses; tendo o cuidado de nunca invocar a própria auctoridade, mas sim o desejo do Khediva, que sollicita as reformas propostas, a permanência do exercito de ocupação e as operações militares na provincia do Soudan, etc.
>
> Uzando d'estes poderosos meios de acção, logo no principio o exercito indígena foi licenciado, ficando só as forças inglesas encarregadas de manter a ordem e fazer cumprir as resoluções que se foram tomando para melhorar os serviços públicos. N'este empenho os agentes inglezes souberam haver-se com a sua reconhecida tenacidade e pericia.
>
> O exercito foi depois reorganizado sob a direcção de officiaes inglezes nos comandos superiores dos corpos, e empregado quasi todo na reconquista do Soudan, na administração das finanças introduziu-se a regularidade da cobrança dos impostos e a severa e exacta aplicação dos fundos públicos; e por egual forma se regularizaram todos os grandes serviços das obras publicas, dos correios e telégrafos, bem como o da exploração dos caminhos de ferro do Estado.
>
> A administração da justiça também lucrou muito com o novo influxo da civilização europêa. Além da admirável instituição dos tribunaes mixtos, que tem conseguido incutir no cérebro dos indígenas a idéa da justiça absoluta, independente, superior a todas as influencias, – há uma organização judicial mais recente, com tribunaes compostos exclusivamente de juízes indígenas, togados, e de alguns inglezes, que se regem por códigos e por um corpo de legislação que se vae promulgando pouco a pouco segundo as necessidades da administração do paiz. (pp.54-5).

Reconhecendo os aspectos positivos da nova orientação britânica – "em todos os ramos da administração do paiz, o Egypto entrou n'um período de completa reorganização economica" (I tomo, 6ª Carta, p.67); os "bellos resultados da boa administração são visíveis e palpáveis, ninguém póde duvidar d'elles, e os próprios arabes reconhecem que sem o impulso estranho nunca o Egypto se teria transformado de um modo tão rápido e brilhante" (I tomo, 6ª Carta, p.68); " reconhecer a superioridade da civilização europea, e a eficaz influencia do protectordo inglez para a regeneração do Egypto" (I tomo, 6ª Carta, p.69); "são os próprios tutelados que afirmam a excellencia da lição que estão recebendo, da aplicação dos verdadeiros princípios da arte de governar, á administração civil e politica do paiz" (I tomo, 6ª Carta, p.70)[15] –,Larcher perspectiva-os como resultado também, sobretudo, da acção de franceses e da colaboração de gregos, italianos e até judeus: "Todavia, é justo confessar, que se os ingleses teem sido tão felizes na sua administração, é porque encontraram já o terreno preparado, e só tiveram que seguir o caminho encetado, desenvolver e aperfeiçoar" (I tomo, 6ª Carta, p.71);

> Pelo activo impulso que souberam dar ao commercio internacional, conseguiram introduzir no paiz o gosto e o uso dos artefactos

> europeus e levar os indígenas ao ponto de sacudirem o torpor da sua monotonia existencial, e adoptarem nas suas vivendas uma certa ordem de conforto de que não tinham notícia, e muito contribuiu para dar ás pessoas e em parte ás coisas umas apparencias, aliaz já muito acentuadas, de civilisação e progresso. (I tomo, 6ª Carta, p.72);

Consideramos estas anotações de José de Souza Larcher o resultado do seu profundo compromisso com a construção e transmissão de uma visão imparcial, em muito resultante da sua experiência vivida no terreno, como ele, no fundo reconhece: "Nada melhor, para formar uma opinião com sólidos fundamentos, do que ir beber á fonte limpa, vêr de visu e pizar o solo onde se passa a acção" (I tomo, 6ª Carta, p.70).

Da mesma forma, o seu 7º Capítulo-Carta procura cruzar eficazmente o que apreendeu da valoração intelectual do passado com o que escolheu do seu contacto com as pessoas. A sua expressão é notável de simplicidade, enquanto transmite uma profunda consciência da dimensão da auto-determinação do povo egípcio:

> Apezar das inegáveis vantagens que teem resultado do protectorado da Inglaterra, a bem da regeneração politica e económica do Egypto, vantagens que estrangeiros e nacionaes não podem deixar de reconhecer, é certo, todavia, que se a qualquer egypcio um europeu perguntar, – se quer continuar a viver sob a tutela inglesa, ou se prefere voltar ao puro governo absoluto do Khediva, não haverá sombra de hesitação na resposta favorável á restauração do governo nacional" (I tomo, 7ª Carta, p.76).

Ao patriotismo e nacionalismo assim defendido talvez não fosse alheio o sentimento e reflexão do alentejano sobre o próprio *Ultimatum* inglês de 1890 que, apesar de formalmente terminado no ano seguinte, com a ratificação do Parlamento português de um tratado anglo-luso, marcaria o final do regime monárquico em Portugal e a emergência do movimento republicano a que José de Souza Larcher aderira já[16]. Não temos "prova documental escrita" desta nossa especulação, mas são consentâneas com ela as seguintes passagens do 7º Capítulo-Carta:

> Não cremos que de principio o governo inglez tivesse já planeado o seu grande projecto de ligar o Egypto ao Cabo, por uma larga faxa de territorio através da África austral; tanto mais que antes do bombardeamento de Alexandria e da derrota de Arabi, não poderia imaginar que a Europa lhe deixasse o campo livre para tentar tudo o que lhe parecesse mais consentâneo aos seus interesses comerciais. (7ª Carta, p.77);
>
> E assim correram anos e conferencias diplomáticas, bem aproveitadas pelo governo inglez em firmar mais o sue domínio; aguardando com placida astucia o momento em que lhe será possível arrancar a mascara com que tem pretendido ocultar os seus ambiciosos e machiavelicos desígnios. (I tomo, 7ª Carta, p.79).

Batalha de Tell el-Kebir, Pintura de Alphonse-Marie-Adolphe de Neuville. National Museums Scotland. © Domínio Público

Batalha de Tell el-Kebir, Pintura de Henri Louis Dupray. © Domínio Público.

Considerações finais

Nas suas *Impressões de Viagem,* José de Souza Larcher acomodou numerosas referências ao Egipto antigo, o passado remoto do país que visitava, bem como em relação ao Egipto moderno, habitado por árabes e muçulmanos mais ou menos subjugados por europeus invasores, sobretudo ingleses e franceses, e em obediência política à Grande Porta.

Resistindo aos sentimentos de parcialidade, as suas apreciações da eficácia e eficiência do protectorado inglês no Egipto são o resultado directo da sua experiência de visitante que, acedendo ao local onde os acontecimentos tiveram lugar, os reconstitui na sua narrativa com o enriquecimento suplementar dessa mesma experiência, vista e ouvida.

A sua narrativa sobre os antecedentes e sobre o protectorado britânico informa, discute e interpreta os dados por si compulsados e, através dessas atitudes, onde, simultaneamente se nota o seu senso político e jornalístico, contribui para formar a opinião dos seus leitores. As suas *Impressões* podem/ devem ter exercido considerável influência sobre eles. A comoção do *Ultimatum* pode ter alimentado em Portugal uma certa recepção dos seus escritos sobre os ingleses no Egipto no I tomo do seu livro, sobretudo pelo tom de crítica severa ao imperialismo inglês que adopta em muitas passagens, susceptível de mobilizar adeptos e adversários das causas inglesas.

Como político e escritor, José de Souza Larcher estava atento ao que passava no mundo. A sua idade e experiência de vida, os ambientes sociais em que se movimentou, em Portugal e no Egipto, e a vivência *in loco,* em muitos dos lugares onde os eventos sobre que escreve se passaram, fazem dos seus Capítulos-Cartas sobre as lutas nacionalistas e imperialistas no Egipto do final do século XIX autênticas crónicas jornalísticas de cobertura dos acontecimentos relatados, mesmo que desfasados no tempo.

Nas suas intervenções, procura sempre manter uma certa imparcialidade, evitando cair na defesa da "superioridade do europeu" e registando as suas observações mais críticas e o seu desconforto político e moral com que recepcionara certos episódios do passado recente por eles cometidos. As suas crónicas comentadas e recheadas de dados históricos, embora arroladas como "impressões de viagem", são, por isso, valiosos documentos do discurso eurocêntrico sobre as relações de poder e sobre a política internacional, sobretudo na lógica anglo-egípcia. Neste sentido, o turista português José de Souza Larcher foi um produtor de história.

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Notas

[1] Os três primeiros textos da *Gazeta de Notícias* foram publicados a 27, 28 e 29 de Setembro e os restantes a 13, 17 e 24 de Outubro (Pereira, 2009, pp.11, 17). A colaboração de Eça com o jornal carioca datava de 24 de Julho de 1880 e prolongar-se-ia até 21 de Setembro de 1897, quase 20 anos, saldando-se por 58 textos publicados em 116 números da *Gazeta* (Pereira, 2009, p.16; Buescu, 2002, p.200-1). No site da Hemeroteca Digital Brasileira (https://bndigital.bn.gov.br/hemeroteca-digital/), aceda-se a *Gazeta de Noticias (RJ) - 1875 a 1879* e, no ano de 1882, vejam-se os textos em questão, na sua publicação jornalística original, na parte inferior da primeira página de cada número. Vide também Queirós (1905; 2002, pp.16, 24, 44, 45, 175-221; 2004), Miné (2020), Siqueira (2023, pp.23-4), Peixinho (2007), Pereira, Bonnici (2008).

[2] Texto de 17 de Outubro de 1882. Vide Queirós (1905, pp.159, 182; 2002, pp.195, 208; 2004, pp.40, 63).

[3] No Cairo, curiosamente, ambos terão ficado hospedados no Hotel Shepheard's, o mais luxuoso hotel da cidade e do Oriente à época ("(…) demos entrada no sumptuoso e vasto hotel Shepheard's" – I tomo, 9ª Capítulo-Carta, p.97). Vide Araújo (1987, p.21) e Coelho (2016, pp.257-8).

[4] Sobre mais dados biográficos de José de Souza Larcher, vide Sales, Mota (2026).

[5] Estabelecidos em 1876, não obstante *shariʿah* locais continuarem a funcionar, os tribunais mistos funcionavam no Egipto, por períodos de cinco anos, com vista a minorar os inconvenientes que resultavam da aplicação da Lei aos estrangeiros aí residentes e das reclamações e contestações diplomáticas que se levantavam quanto à competência e legalidade da execução das sentenças.

[6] A designação "Capítulo-Carta" é usada na edição e é explicada por José de Souza Larcher no texto "Advertencia", com que abre o I tomo:

> Logo que cheguei ao Egypto escrevi a alguns amigos sobre as coisas que ia observando no paiz que visitava; mas depois, reconhecendo que havia margem para largas considerações, deliberei-me a dar, ao que já tinha dito nas minhas cartas, maior desenvolvimento; tratando sucessivamente de diversos assumptos e estudos que tenho a satisfação de dedicar, cada um de per si, a alguns parentes, amigos e correligionarios, a quem peço vénia e bom, acolhimento para o meu modesto trabalho.

[7] Uma outra passagem na p.11 (I tomo, 1° Capítulo-Carta) é muito elucidativa desta conciliação entre o observado e o lido. Diz José de Souza Larcher, sobre o Canal de Suez:

> O canal traçado em linhas rectas na arêa, é uma obra que **á vista** nada apresenta de assombroso. Para se avaliar o seu valor e importancia **é preciso lêr** a descripção dos trabalhos, e ahi, n'esse documento de completa autenticidade se encontrará a prova de quantos milhares de braços e de quantas centenas de milhões de francos foi necessario empregar para levar a cabo a empresa; e só assim se poderá reconhecer que é uma obra colossal, senão pelo que ostenta á flor da terra, com certeza pelos maravilhosos resultados que está produzindo a bem do commercio e da civilização.

Os destaques são nossos. Acreditamos que a mesma atitude esteve associada à reconstituição histórica das motivações e dos efeitos da invasão britânica e dos apontamentos sobre a política internacional da sua época esboçados por J. S. Larcher

[8] Textos I, II e V, de 27 e 28 de Setembro e 17 de Outubro, na *Gazeta de Notícias*. Aliás, o segundo destes textos é, na prática, exclusivamente dedicado à descrição da acção de Arabi (Queirós, 1905, pp. 132, 135-148; 2002, pp. 179-189; 2004, pp. 15-29). Para Eça de Queirós, Arabi pretendia o fim da autoridade absoluta do Khediva Taufik, a reforma da utilização dos dinheiros públicos consumidos em pesados impostos pagos aos vorazes credores franceses e ingleses e o abolir dos privilégios fiscais de que os estrangeiros gozavam no Egipto (Coelho, 2016, p.261).

[9] Mencione-se que, a 8 de Fevereiro de 1892, no *Suplemento Literário* n° 2 da *Gazeta de Notícias* do Rio de Janeiro, Eça de Queirós publicou um texto intitulado "O Novo Quediva do Egipto" onde dava conta da morte de Taufik, o filho de Ismail Pachá, ocorrida um mês antes, a 7 de Janeiro, e da subida ao poder, com 17 anos, de Abbas Hilmy II, o Khediva com que Larcher se entrevistou pessoalmente várias vezes no Egipto em 1898 (Queirós, 2002, pp.31-2; Sales, 2024). Anote-se que foi este Khediva que inaugurou, logo no seu primeiro ano de vice-reinado, a 17 de outubro de 1892, o Museu Greco-Romano de Alexandria, o mais antigo edifício do Egipto preparado arquitectonicamente com o objectivo de preservar e expor antiguidades.

[10] Também Eça de Queirós fala dos "luxos de Salomão" do Khediva Ismail que muito crítica e que trata também como "esse esplêndido perdulário" (*Gazeta de Notícias*, de 28 e de 29 de Setembro de 1882, 1; Queirós, 1905, pp.140, 161; 2002, p.184; 2004, 22, 41; Coelho, 2016, p.259). A historiografia viria a olhá-lo basicamente sob os mesmos ângulos: ora como "um tolo perdulário", ora como "um reformador perspicaz, embora extravagante" (Cleveland, Bunton, 2009, p.95).

[11] Eça de Queirós apelida-o de "excelente e pacato moço", "amável príncipe tão doce ao estrangeiro" (Queirós, 1905, pp.132, 142; 2002, pp.179, 185; 2004, pp.15, 23). Vide também Miné (2020, p.418).

[12] Como escreve M. W. Daly, "The events of 1882 mark a watershed in the modern history of Egypt" (Daly, 1998, p.239) ou, como defende Donald Malcolm Reid, "The Alexandria riot, British bombardment, and the ensuing invasion propelled the revolution into its third stage, the final break with Tawfiq and war with Britain." (Reid, 1998, p.231). Por seu turno, reforçando a importância deste momento histórico, Cleveland e Bunton sustentam: "The British occupation of Egypt produced one of the most significant colonial encounters of the modern era" (Cleveland, Bunton, 2009, p.103). Vide também Hopkins (1986).

[13] Recorde-se que também Eça de Queirós, que visitara a cidade em 1869, condenara o bombardeamento de Alexandria, logo no primeiro artigo publicado a 27 de Setembro de 1882, p. 1, cinco ou seis semanas após o acontecimento, na *Gazeta de Notícias* do Rio de Janeiro. Confesso admirador dos Ingleses, repudia, todavia, o desaparecimento da cidade, "pela quarta vez na história" às mãos do "snr. William Gladstone" (então Primeiro-Ministro do Reino Unido) e da "brusca aggressão de uma frota de doze couraçados". Considera o acto como de "politica primitiva":"ser forte, cahir sobre o fraco, destruir vidas e empolgar fazendas." (Araújo, 1987, pp.224-226, 239; Coelho, 2016, p.255); Vide também Queirós (1905, pp.125-133; 2002, pp.175-221; 2004, pp.9-16).

[14] Derrotado pelos britânicos em Tell el-Kebir, Ahmed Arabi exilou-se no Ceilão (actual Sri Lanka) e só regressaria ao Egipto em 1911, onde acabaria por falecer, no Cairo, a 21 de Setembro desse ano. Vide Cleveland, Bunton (2009, p.100).

[15] O tom de reconhecimento pela "severa e ilustrada administração" inglesa no Egipto volta a surgir no II tomo, 23º Capítulo-Carta, pp.89, 91, 94-6, onde se volta a acentuar a procurada imparcialidade crítica do Autor:

> Temos criticado muitos actos da politica ingleza ao que ela tem de cego egoísmo, como temos louvado os efeitos admiráveis da sua acção administrativa e económica, inteiramente livres de preconceitos políticos e nacionaes, e de qualquer outra influencia que poderia adulterar as nossas impressões, e desviar da devida rectidão as nossas apreciações" (II tomo, 23ª Carta, p.96).

[16] Anote-se que, no II tomo, 30ª Carta, Larcher faz uma alusão directa ao *Ultimatum,* apelidando-o de "o ominoso ultimatum de 11 de janeiro de 1890" (p.206). A referência é feita numa narrativa destinada a refletir sobre a "alliança com a Inglaterra" (p.203) que, após se mencionarem vários episódios da mesma, ao longo do tempo, se conclui com um enfático "a Inglaterra nunca attende para nos ser útil, mas que sempre invoca para conseguir os seus fins, contando com a nossa ingenua annuencia" (p.214).

Vinte anos da convenção de Faro

Twenty years since the Faro Convention

Guilherme Oliveira Martins

Resumo

Ao celebrarem-se os vinte anos da Convenção quadro do Conselho da Europa sobre o Valor do Património Cultural na Sociedade Contemporânea, de outubro de 2005, importa olhar o Património Cultural na sua relação direta com as pessoas e as comunidades, de modo a considerar e a concretizar uma prioridade efetiva à Cultura das pessoas, da memória e da criatividade. Karl Jaspers falava da Europa como sinónimo de liberdade, história e ciência. Liberdade, como vitória sobre o arbitrário, porque a queremos quando sabemos que a não temos. História enquanto conhecimento da sociedade. Ciência enquanto conhecimento rigoroso e aberto. O conceito inovador de património cultural envolve o património material, monumentos e documentos; o património imaterial, as tradições e os costumes; o património natural e paisagístico; património digital e criação contemporânea. A Convenção constitui o mais moderno tratamento do tema, recebendo os melhores contributos, como a noção de património imaterial da UNESCO. A noção de Património comum europeu constitui um fator essencial como contributo para a paz, coesão social e progresso cultural, educacional e científico.

Palavras-chave Património Cultural, Liberdade, História, Ciência, Memória, Herança.

Guilherme Oliveira Martins
Presidente Conselho Geral - Universidade Aberta

0000-0001-7807-0269

Abstract

Now that we are celebrating the twentieth anniversary of the Council of Europe Framework Convention on the Value of Cultural Heritage for Contemporary Society, signed in October 2005, it is imperative to consider cultural heritage in the context of its direct relationship with people and communities, so as to give effective priority to people's culture, memory and creativity. Karl Jaspers referred to Europe as synonymous with freedom, history and science. Freedom, as victory over arbitrariness, because we want it when we know we do not have it. History as knowledge of society. Science as accurate and open knowledge. The innovative concept of cultural heritage encompasses tangible heritage, monuments and documents; intangible heritage, traditions and customs; natural and landscape heritage; digital heritage and contemporary creation. The Convention is the most modern treatment of the subject, incorporating the best contributions, such as UNESCO's notion of intangible heritage. The notion of common European heritage is an essential factor in contributing to peace, social cohesion and cultural, educational and scientific progress.

Keywords: Cultural Heritage, Freedom, History, Science, Memory, Legacy.

Fig. 1. Alexandre Herculano por João Pedroso

"Nossos pais destruíram por ignorância e ainda mais por desleixo: destruíram, digamos assim, negativamente: nós destruímos por ideias ou falsas ou exageradas; destruímos ativamente; destruímos, porque a destruição é uma vertigem desta época. Feliz quem isto escreve, se pudesse curar alguém da febre demolidora; salvar uma pedra, só que fosse, das mãos dos modernos hunos!"

Alexandre Herculano, *Opúsculos*.

Num momento em que os cidadãos europeus são chamados a criar elos permanentes que garantam a existência de uma autêntica diversidade cultural, como fator de coesão e de confiança, em lugar da fragmentação, devemos repensar os fundamentos de uma Europa plural, como realidade aberta ao mundo e às diferentes culturas, consciente da sua própria memória e das suas raízes, baseada na diversidade de pertenças e na procura de valores comuns. Eis por que temos de olhar o Património Cultural na sua relação direta com as pessoas e as comunidades, de modo a considerar e a concretizar uma prioridade efetiva à Cultura das pessoas, da memória e da criatividade. Karl Jaspers falava da Europa como sinónimo de liberdade, história e ciência. Liberdade, como vitória sobre o arbitrário, porque a queremos quando sabemos que a não temos. História, como encontro e diálogo, no sentido da compreensão do tempo e fator de emancipação. Ciência, como exigência de verdade – "não só como jogo de pensamento lógico, mas como vontade absoluta, universal de conhecer o conhecível".

A diversidade cultural e a pluralidade de pertenças obrigam a recusar as identidades fechadas. As identidades só ganham pleno sentido quando sejam abertas e disponíveis para dar e receber, e para assegurarem um permanente diálogo entre a tradição e a modernidade. Tradição significa transmissão, dádiva, entrega, gratuitidade. Modernidade representa o que em cada momento acrescentamos à herança recebida, como fator de liberdade e de emancipação, de autonomia e de criação. A novidade resulta sempre desse diálogo entre o que recebemos e o que criamos. E a cultura situa-se no ponto de encontro e de saída – não em confronto com a natureza, mas complementarmente a ela. Os monumentos, as casas, os lugares, as regiões, os povos, as nações têm um espírito, sempre feito de diferenças e de interdependência.

Temos, por isso, que entender o "espírito dos lugares" e de transformar essa compreensão num modo de nos enriquecermos culturalmente a partir do diálogo entre o que recebemos dos nossos antepassados, correspondente ao património material e imaterial, e o que criamos de novo, a contemporaneidade – que nos insere na História, onde tudo se transforma. No entanto, deparamo-nos com a tentação do esquecimento e da indiferença. E o certo é que a falta de memória histórica nos leva pelos caminhos da repetição trágica ou da violência cega. Que é a decadência senão a confusão entre memória, desatenção e repetição? E a repetição de gestos e atitudes, para além do poder invocatório, conduz-nos, se não houver a capacidade de dar atenção e de renovar, à ausência de vitalidade. E que é a barbárie senão a falta de memória? Os novos hunos de que fala Herculano praticam a indiferença e o esquecimento. E a verdade é que a amnésia histórica e cultural conduz à subalternização e à irrelevância. Tradição e modernidade são, de facto, faces da mesma moeda, uma e a outra têm de se alimentar mutuamente. A história das sociedades é feita de um diálogo permanente entre a força das raízes antigas e a vontade das novas gerações.

E se a criação exige novidade e rutura, a verdade é que a criação cultural e artística se faz sempre tendo em consideração a herança cultural e o conhecimento do tempo que nos antecede.

Conhecer e compreender o Património como fator de inovação e de criatividade, de paz e de democracia significa aprender com a diferença, isto é, aprender a ser com os outros. Não basta proclamar grandes princípios abstratos, é indispensável lançar pontes, realizar iniciativas comuns, reler a História à luz da compreensão dos conflitos e da sua superação pacífica e democrática, recusar que o pêndulo apenas indique o sonho ou o pesadelo. Salvar uma pedra significa um serviço de respeito, mas mais do que isso de estudo e de compreensão de onde provimos. Uma "cultura de paz" tem de se realizar com base no conhecimento e na compreensão, na educação e na cultura, na ciência e na comunicação, como afirmou o então diretor geral da UNESCO Federico Mayor. No entanto, falar dessa "cultura da paz" e da "sociedade de cultura" baseadas no conhecimento e na aprendizagem não pode significar a invocação de uma mera "boa intenção", trata-se, sim, de criar verdadeiros fatores de prevenção contra a barbárie e o esquecimento, contra a guerra e a injustiça, contra a discriminação e a violência – ligando o saber, a criatividade, a liberdade e a responsabilidade. Estamos no cerne da "paideia" e da "humanitas", para as quais educação e cultura se ligam para despertar consciências e para criar e construir uma cidadania autónoma, ativa e responsável.

As fronteiras visíveis e invisíveis têm de se tornar linhas de encontro, de respeito, de troca, de entendimento, de regulação pacífica de conflitos, mas também de interrogação e de dúvida sobre o que divide e separa e sobre as razões dos conflitos e das incompreensões. Como afirmou Jacek Wosniakowski, a nova ideia de fronteira pressupõe, mais do que o conhecimento, a compreensão mútua. Nos Balcãs todos se conhecem demasiado bem e não foi isso que reduziu a conflitualidade. A fronteira deve aprofundar o que une e o que distingue – porque urge distinguir para unir. A cultura deve, assim, buscar os fatores unificadores e universalizantes nas diferenças, uma vez que só assim se poderá começar a regular o dilema entre liberdade e diferença, e a complementaridade entre igualdade e distinção. E se a sociedade humana é por definição conflitual, importa promover a igual consideração e o respeito como valores fundamentais da sociedade aberta. Todos nos lembramos dos efeitos negativos das construções políticas e sociais artificiais. Quando se perdem os fatores formais de coesão, a conflitualidade emerge violenta e desregulada. Eis a razão por que as novas noções de património comum e de fronteira têm de ser aprofundadas no plano social e cultural. Nas sociedades abertas, as fronteiras físicas e sociais devem ser assumidas como lugares de distinção e de diferença, mas também como linhas de proximidade. Todos sabemos que as rivalidades maiores são as dos povos vizinhos, e no entanto, a melhor maneira de as orientar positivamente é encontrar projetos comuns que os levem a compreender no dia a dia que dependemos uns dos outros, sem prejuízo da existência natural de rivalidades, que são o sinal da diferença.

Nada pior do que alimentar ilusões sobre realidades impossíveis. E o Património Cultural, num sentido amplo, poderá levar-nos a compreender a realidade humana, não como imagem idílica, mas como encruzilhada de vontades e de dúvidas, contra o fatalismo, os determinismos, a ignorância e o esquecimento. A Educação como aprendizagem permanente a partir da transmissão dos saberes, do exemplo e da experiência, tem, por isso, um papel fundamental no combate pela "sociedade de cultura", pela "cultura da paz" e pela defesa e salvaguarda de um património comum, da humanidade, dos povos e das pessoas. Seguindo o ensinamento de John Dewey, que o nosso António Sérgio cultivou, trata-se de entender a formação cívica não como uma antecâmara para a vida, mas como uma vivência quotidiana da liberdade e da responsabilidade, e da lenta, gradual e permanente construção educativa (bildung). E quando falamos

de cultura temos de nos reportar sempre ao ato de educar, que permite relacionarmo-nos com a natureza aproveitando-a, protegendo-a e desenvolvendo-a. E o património cultural, como realidade complexa, tem de ser devidamente considerado – desde o código genético e do genoma humano, até às tradições, às comunidades, às instituições, aos hábitos e costumes, num conjunto vasto do que designamos como património imaterial (o modo como os artesãos trabalham, como a culinária se desenvolve, como as pessoas e as comunidades se relacionam), passando pelos vestígios arqueológicos, pelos monumentos, pelo modo de organização das populações e das cidades, mas também pela valorização da criação contemporânea e pela busca de uma relação equilibrada nesse diálogo entre o que hoje temos e queremos e aquilo que recebemos de antanho.

Todas as pessoas têm o direito de se implicar e de participar na valorização do Património Cultural, segundo as suas escolhas, como modo de assegurar o direito a tomar parte livremente na vida cultural. Daí a importância de promover e aprofundar a participação dos cidadãos na gestão e preservação do Património Cultural, bem como a necessidade de colocar a pessoa humana e os seus valores no centro de um conceito novo, alargado e transversal, de património cultural, como recurso do desenvolvimento durável e da qualidade de vida.

O pluralismo, a liberdade, a abertura, a compreensão do outro e do diferente são peças fundamentais na "sociedade de cultura", onde a dignidade humana é colocada no centro da organização humana. De facto, as grandes crises da História superaram-se pela lenta e segura tomada de consciência dos cidadãos e da sociedade e pelo reconhecimento do valor universal da dignidade humana. E não podemos esquecer que a coesão social, económica, cultural e territorial exige trocas e projetos comuns, justiça e equidade. Essas trocas, esse enriquecimento mútuo, permitem que os choques de gerações produzam efeito positivo, num primeiro momento pelo confronto e pela rutura e, num segundo tempo, pela incorporação do novo no património comum, aceite como fazendo parte do acervo histórico. Daí a importância de um verdadeiro diálogo entre gerações que supere a "febre demolidora" de que falava Herculano.

Donde a necessidade de termos uma Convenção-Quadro do Conselho da Europa sobre o Valor do Património Cultural na Sociedade Contemporânea, assinada na cidade de Faro, há vinte anos, a 27 de outubro de 2005. De facto, temos de atribuir um valor especial ao Património Cultural e à memória, como realidades que se projetam no presente e que contribuem para um mundo melhor. Trata-se de um ordenamento jurídico de enquadramento, que parte da exigência do reconhecimento da importância da memória e do valor do património cultural na sociedade. Afinal, o património cultural está, cada vez mais, na convergência dinâmica entre a herança material e imaterial, representada pelos monumentos e pelas tradições, pelos costumes e pelas mentalidades, pela natureza e pela paisagem, de um lado, com a criação cultural contemporânea, a inovação e a modernidade, de outro.

Trata-se, no fundo, de tentar entender a importância fundamental do valor acrescentado que as novas gerações somam e incorporam na realidade cultural dinâmica de que somos protagonistas, não como realidade autónoma ou de geração espontânea, mas como algo que se insere na afirmação histórica de uma humanidade que evolui através da sua ilimitada capacidade de contrariar os determinismos de um destino cego. E assim um monumento histórico, um lugar, uma tradição têm de ser defendidos e preservados não só porque representam um sinal de presença e de vida de quem nos antecedeu, mas também porque contribui decisivamente para enriquecer a nossa vida e a nossa existência. Não estamos sós, em cada momento, a História faz-se com os contemporâneos e com aqueles que tornaram possível a nossa existência e constituíram as gerações que nos antecederam. E que são os conceitos de Paideia e de Humanitas

senão o reconhecimento de que a sabedoria humana tem de assentar no que devemos às gerações que nos antecederam e aos outros com que lidamos e que devemos respeitar?

A finalidade da Convenção de Faro do Conselho da Europa é o reconhecimento de "valor" para a sociedade do património histórico e da cultura, considerados como realidades dinâmicas, resultado de uma fecunda dialética entre o que recebemos e o que legamos relativamente à criação humana. Os valores não são objetos ideais. E os fenómenos culturais participam dessa qualidade, não cabendo em "modelos estáticos", devendo, sim, inserir-se no horizonte da "experiência histórica". Perante uma Convenção internacional, de âmbito europeu, com uma clara referência universalista, até considerando o trabalho que tem vindo a ser realizado pela UNESCO no âmbito da diversidade cultural e do património imaterial, a consagração de obrigações de âmbito universal, centradas na expressão universalista da dignidade da pessoa humana, assentes em constantes axiológicas, torna-se indispensável pôr no centro das preocupações do instrumento jurídico uma teia complexa de direitos e deveres, de garantias e responsabilidades, de instrumentos de acompanhamento e avaliação, que possam fazer convergir não só a salvaguarda concreta, mas também a proteção do património histórico e cultural no âmbito de uma cultura aberta e universalista de direitos e deveres fundamentais.

A diversidade cultural e o pluralismo têm de ser preservados, com especiais cautelas, contra a homogeneização ou a harmonização indiferenciada. E se falamos de um "património comum europeu", a verdade é que estamos perante a construção inédita e original de uma "supranacionalidade" baseada na extensão do Estado de direito, na diversidade das culturas, na soberania originária dos Estados-nações, na dupla legitimidade (dos Estados e dos cidadãos ou povos), na adequação de objetivos comuns à circunstância da heterogeneidade económica e social, pondo a tónica na criação de um espaço de segurança e de paz, numa maior partilha de responsabilidades nos domínios económico e do desenvolvimento durável. Eis por que se tornou importante, em nome da dignidade da pessoa humana e da procura de um "património ou herança comum" considerar, em estreita ligação com o reconhecimento de um "código genético cultural" que recebemos, os valores que o homem intui na sua experiência individual e social e que, depois, reelabora racionalmente, com ideias de proporção e de ordem, com vista à realização do bem comum, segundo uma proporção exigida pelos valores da pessoa e pela conservação e desenvolvimento da cultura.

Trata-se de procurar os caminhos adequados para garantir a um tempo o reconhecimento das diferenças culturais contra todas as tentações de homogeneização e de centralização uniformizadora, bem como da importância da preservação e do desenvolvimento da proteção dos valores comuns da cultura. Fora da absolutização do Estado ou da sua menorização, em lugar do Estado dirigista e do Estado mínimo, o que se impõe é equilibrar a iniciativa pública e a responsabilidades dos cidadãos e as legitimidades centradas nos Estados, nos povos e nos cidadãos, segundo a partilha de soberanias inerente ao alargamento das experiências democráticas, a partir do respeito universal dos direitos, liberdades, garantias das pessoas e das responsabilidades cívicas

A cultura, enquanto criação humana exige a compreensão do tempo, da história e da sociedade. Assim, a obra de arte, a proposição filosófica, a norma jurídica, uma vez criadas ou formuladas, adquirem vida própria, tornam-se independentes do seu autor e do seu criador, tornam-se portadoras de uma plenitude de ser e de um sentido próprio, aberto ao conhecimento e à interpretação. Por um lado, devemos ter presente uma visão marcada pela História, que reforça a circunstância existencial e social e que projeta a vida humana para além de uma visão fechada e redutora. E a saída está na consideração de uma tripla dimensão da vida humana, como

realidade individual, social e histórica.

E se falamos da Convenção-Quadro do Conselho da Europa, temos de referir que não se trata de um mero instrumento jurídico fechado e estático, correspondente a um sistema de direitos e obrigações. Estamos diante de um instrumento mobilizador de vontades, centrado no "valor" do património cultural, capaz de suscitar o encontro entre a memória e a inovação criadora e de considerar a tripla dimensão da vida humana, como realidade individual, social e histórica. Daí ter de se reconhecer o "valor do património cultural", como memória comum e como vida, para a sociedade e para as pessoas. E a nova Convenção recoloca a noção de património cultural num contexto que evoluiu consideravelmente desde a adoção das convenções de proteção do património dos anos setenta e oitenta.

O texto inscreve-se, pois, na perspetiva da mundialização e no quadro político de uma Europa mais coesa em torno de valores comuns à escala do continente. O Conselho da Europa continua a desempenhar um papel pioneiro na reflexão sobre o significado do património nas nossas sociedades. Trata-se do culminar de uma reflexão levada a cabo pelo Conselho da Europa, desde os anos 70, em matéria de "conservação integrada" dos bens culturais. Sem retornar a mecanismos de proteção já cobertos pelas Convenções precedentes, o texto de 2005 insiste nas funções e no papel do património: trata-se de passar do "como preservar o património e segundo que procedimento", à questão do "porquê e para quem dar-lhe valor". Se é importante preservar e saber como fazê-lo, tornou-se indispensável introduzir o elemento teleológico – por que razão e com que finalidade procedemos à preservação e à conservação, longe de uma perspetiva de antiquário ou de "*bric-à-brac*", mas dando um valor social e histórico aos bens do património material e imaterial?

Esta perspetiva concretizou-se através do entendimento segundo o qual o conhecimento e a prática do património cultural têm a ver com o direito de os cidadãos participarem na vida cultural, de acordo com os direitos e liberdades fundamentais comummente aceites. O projeto considera, assim, o património cultural como um valor e um recurso que tanto serve o desenvolvimento humano em geral, como serve um modelo de desenvolvimento económico e social assente no uso durável dos recursos, com respeito pela dignidade da pessoa humana, enquanto "valor primordial ou o valor-fonte de todos os demais valores". E cabe ao Conselho da Europa, organização baseada na promoção da liberdade, dos direitos fundamentais e da dignidade da pessoa humana e dos princípios democráticos, introduzir este novo conceito de património cultural orientado para as pessoas, mais do que para os objetos, de acordo com o entendimento da cultura como criação humana.

Estamos, deste modo e antes do mais, diante de uma Convenção-quadro, uma espécie de Convenção-marco, isto é, um instrumento de referência, apto a influenciar outros instrumentos jurídicos de âmbito nacional e internacional. Isto significa que estamos diante de um instrumento que, sem duplicar a ação da UNESCO, define objetivos gerais e identifica domínios de ação, bem como direções e pistas em cujo sentido as partes aceitam progredir, deixando a cada um a escolha e a autonomia para optar pelos meios de realização melhor adaptados à sua tradição política e jurídica.

É assim uma Convenção-quadro, já que não cria "direitos executórios" diretamente aplicáveis nos países, mas lança um processo de cooperação entre os Estados, convidando-os à atualização e ao progresso das suas políticas do património em benefício de toda a sociedade. Este tema foi, aliás, o mais controverso aquando do processo de discussão sobre a Convenção, antes de a mesma ser aberta à ratificação pelos Estados-membros do Conselho da Europa, uma vez que alguns suscitaram receios ligados à eventual exigência de novos meios para concretizar a Convenção.

A Convenção-quadro visa essencialmente mobilizar vontades (através de um instrumento jurídico autónomo e com força própria) no sentido de tornar o património cultural um fator de paz e de cooperação, ao contrário do que muitas vezes aconteceu no passado em que o património cultural e as diferenças culturais estiveram (ou ainda estão) no epicentro dos conflitos. Um templo com diversas referências históricas e culturais, religiosas e sociais ao longo do tempo tem de ser visto como um lugar de encontro e de memória, referência de humanidade, facto que só enriquece a sua atual utilização, religiosa ou profana, em nome do respeito e da preservação do espírito dos lugares, segundo uma cultura de paz.

Definido ao longo do tempo pela ação humana, o património cultural, longe de se submeter a uma visão estática e imutável, passa a ter de ser considerado como um "conjunto de recursos herdados do passado", testemunha e expressão de valores, crenças, saberes e tradições em contínua evolução e mudança. O tempo, a história e a sociedade estão em contacto permanente. Nada pode ser compreendido e valorizado sem esse diálogo extremamente rico. Usando a expressão de Rabelais, estamos sempre perante "pedras vivas", já que as "pedras mortas" dão testemunho das primeiras.

O património cultural surge, nesta lógica, como primeiro recurso de compromisso democrático em prol da dignidade da pessoa humana, da diversidade cultural e do desenvolvimento durável. E constitui um capital cultural resultante do engenho e do trabalho de mulheres e homens, tornando-se fator de desenvolvimento e incentivo à criatividade. Quando falamos de respeito mútuo entre culturas e as diversas expressões da criatividade e da tradição estamos, assim, a considerar o valor que a sociedade atribui ao seu património cultural e histórico ou à sua memória como fator fundamental para evitar e prevenir o "choque de civilizações", mas, mais do que isso, para criar bases sólidas de entreajuda e de entendimento.

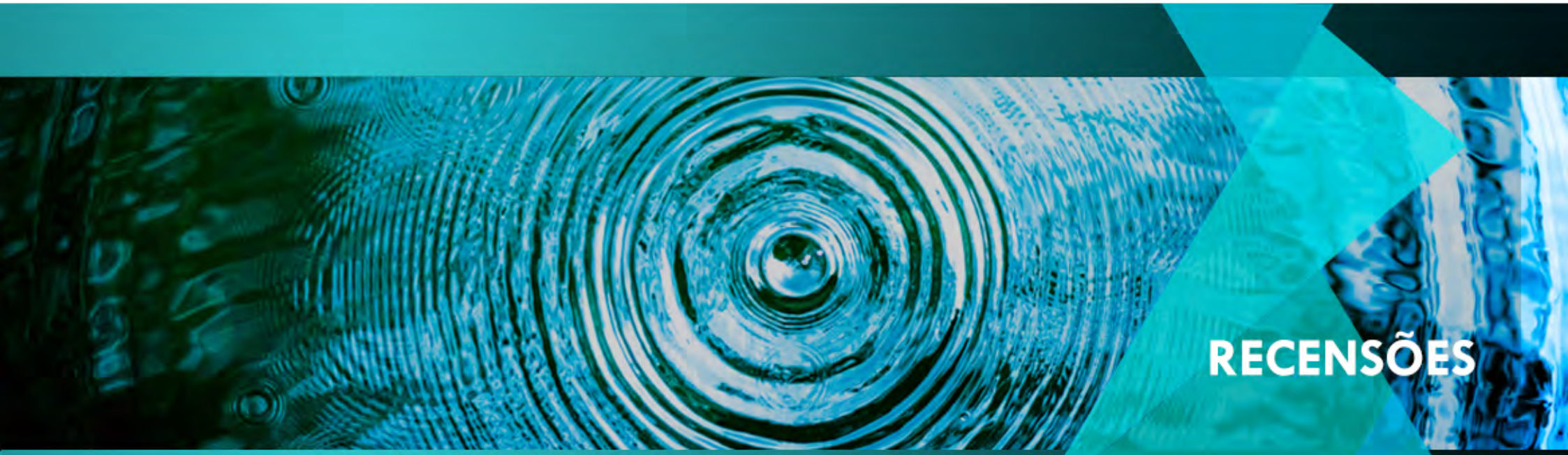
A originalidade de adotar o conceito de "património comum da Europa" tem de ser vista como um elemento dinamizador de uma cidadania ativa e aberta. Somos cidadãos e une-nos um sentimento de pertença comum e os elos que se reportam a uma história viva, simbolizada e representada por uma herança (*heritage*), pelo património material e imaterial e pela capacidade de tornar presente essa invocação, através da vitalidade da criação contemporânea. O "valor" surge, assim, no "horizonte da experiência histórica", fora de qualquer conceção desenraizada. Património comum está, deste modo, na encruzilhada das várias pertenças e no ponto de encontro das várias complementaridades. Indo mais longe do que outros instrumentos jurídicos e políticos e do que outras convenções, o texto visa prevenir os riscos do uso abusivo do património, desde a mera deterioração a uma má interpretação enquanto "fonte duvidosa de conflito". Quantas vezes um mesmo bem patrimonial pode estar ligado a culturas e tradições diferentes. Um templo pode ter na sua existência referências muito diferentes – pode ter sido sinagoga, igreja cristã e mesquita muçulmana. As mudanças fizeram-se tantas vezes violentamente, e haverá a tendência para valorizar apenas a conceção dominante atual, como acontece e Istambul com Santa Sofia. Caberá à sociedade encontrar o denominador comum, que permita evitar ser aquele monumento fonte de conflito. Nesta perspetiva, o património cultural fica no ponto de convergência entre um tempo conflitual e a procura de um consenso de valores e ideais defendido pelo Conselho da Europa.

Impõe-se o reconhecimento mútuo do património inerente às diversas tradições culturais que coexistem e uma responsabilidade moral partilhada na transmissão do património às futuras gerações. Não esqueçamos "o contributo do património cultural para a sociedade e o desenvolvimento humano", no sentido de incentivar o diálogo intercultural, o respeito mútuo e a paz, a melhoria da qualidade de vida e a adoção de critérios de uso durável dos recursos culturais do território. Daí a importância

da "cooperação responsável" na sociedade contemporânea, através da ação conjugada dos poderes públicos, do mundo da economia e do voluntariado.

A Convenção-quadro de Faro surge como um lógico corolário da ação do Conselho da Europa. A partir de instrumentos já existentes, a nova Convenção conduzirá à troca de boas experiências e à difusão de modelos elaborados em comum. Numa sociedade marcada pela mudança a nova Convenção constitui um passo excecionalmente positivo. E poderemos mesmo pensar num "Plano Europeu para a gestão durável dos recursos patrimoniais", a partir do novo entendimento e dos novos compromissos. Perante a exigência do reconhecimento mútuo do património inerente às diversas tradições culturais que coexistem e de uma responsabilidade moral partilhada na transmissão do património às futuras gerações, realizamos um exercício prático, onde, a propósito da herança cultural e da salvaguarda de marcos de memória, descobrimos a importância do diálogo entre valores e factos, entre ideais e interesses, entre autonomia e heteronomia.

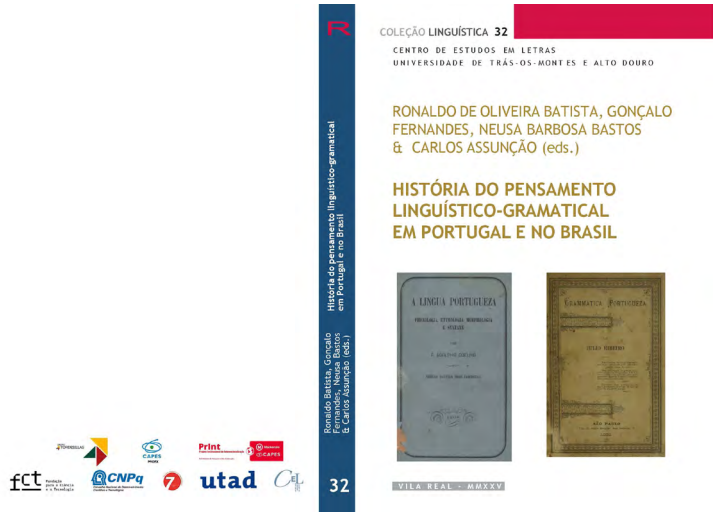
Fig. 2. Sede do Conselho da Europa em Estrasburgo
https://upload.wikimedia.org/wikipedia/commons/d/d9/Council_of_Europe_Palais_de_l%27Europe.JPG



RECENSÕES

História do Pensamento Linguístico-Gramatical em Portugal e no Brasil de Batista, Ronaldo de Oliveira; Fernandes, Gonçalo; Bastos, Neusa Barbosa & Assunção, Carlos (eds) (2025)

Paulo Osório



O Centro de Estudos em Letras (CEL) na Universidade de Trás-os-Montes e Alto Douto tem dedicado uma parte significativa da sua atividade científica ao estudo da Historiografia Linguística, pautando-se pela contínua sistematização de grandes obras (gramáticas, dicionários, guias de conversação, entre outras) que marcaram o pensamento gramatical em língua portuguesa. Essa abrangência do estudo da historiografia lusófona tem feito com que esta Unidade de I&D tenha vindo a estabelecer laços de investigação pautados por uma notória internacionalização.

Cumprindo esta vontade, sob a chancela do referido Centro, foi recentemente publicado, em abril de 2025, o livro *História do Pensamento Linguístico-Gramatical em Portugal e no Brasil* (volume 32 da Coleção Linguística do CEL), resultando de uma organização conjunta de Ronaldo de Oliveira Batista (Brasil), Gonçalo Fernandes (Portugal), Neusa Barbosa Bastos (Brasil) e Carlos Assunção (Portugal), proeminentes investigadores na área da Historiografia Linguística[1]. Tratando-se de uma obra de elevado fôlego científico e de um exemplar rigor metodológico, a coletânea em apreço foi galardoada, muito recentemente, pela Academia Brasileira de Filologia com o Prémio Antenor Nascentes.

Paulo Osório
Universidade Aberta, Lisboa, Portugal
Centro de Linguística da Universidade de Lisboa, Lisboa, Portugal
0000-0001-6009-6970

O volume organiza-se em cinco eixos, tendo cada parte temática a visão de investigadores portugueses e a perspetiva de estudiosos brasileiros. Assim, a coletânea traça um panorama comparativo Portugal/Brasil no que concerne a algumas das principais tradições gramaticais, recortando um longo período cronológico que vai desde as origens do pensamento historiográfico (século XVI) até à atualidade. Como referem os editores na Introdução (p. V):

> (…) esses pontos de partida incidem sobre um questionamento subjacente em todos os capítulos: como apresentar e compreender manifestações históricas ligadas a realidades e recortes temporais que são revistos em tom interpretativo por aqueles que reveem o passado e tentam lhes atribuir significados?

As áreas temáticas abordadas no livro são: (i) «Marcas de tradição gramatical»; (ii) «Uso e norma em instrumentos linguísticos»; (iii) «Visão racionalista na gramática»; (iv) «Apêndices gramaticais: pontuação, estilística e outras questões» e (v) «Ortografias, suas diretrizes e regulamentações». Com um total de 264 páginas, o volume assume uma estrutura

clara, coerente, dando voz a uma comparação sistemática e crítica dos estudos de Historiografia Linguística realizados *aquém* e *além* Atlântico, mas alinhados coerentemente na sua conceção epistemológica. Não é objetivo fundamental da obra o estabelecimento de uma mera cronologia da tradição gramatical, mas antes levar a cabo uma análise conceptual dessas mesmas tradições. No entanto, entre muitos aspetos que fazem deste volume uma obra de referência, parece-me fundamental sublinhar o modo como os diferentes capítulos, comparando duas visões – a de Portugal e a do Brasil, ilustram a especificidade de cada tradição gramatical. No caso dos capítulos elaborados por investigadores brasileiros é particularmente interessante a discussão em torno das especificidades do espaço brasileiro que é naturalmente caracterizado por uma forte tendência de contacto linguístico.

Não farei nesta recensão uma síntese de cada capítulo, aliás particularmente bem conseguida pelos editores do volume na «Introdução» (pp. V-X). Acresce que a obra se encontra em acesso aberto na página do CEL, podendo e devendo ser consultada em https://www.utad.pt/cel/en/home/cel-collections/. Todavia, poder-se-á afirmar que a qualidade científica dos capítulos é notória.

Os textos da autoria dos investigadores brasileiros distinguem-se pelo seu carácter analítico e pela atualização teórica, dialogando com debates contemporâneos sobre "norma", "uso" e "tradição". Os capítulos da autoria de investigadores portugueses apresentam igualmente uma sólida erudição histórica, problematizando conceitos fundamentais na área em apreço. Entre os muitos méritos do volume, destacam-se: (i) o alinhamento explícito com os princípios, formais e metodológicos, da Historiografia Linguística; (ii) a diversidade equilibrada de fontes, incluindo gramáticas missionárias, humanistas, racionalistas e científicas e (iii) a capacidade de integrar discussões clássicas (tradição normativa, racionalismo, comparativismo) com questões atuais, como variação, padronização e história social do português.

Este volume combina, pois, rigor historiográfico com uma sensibilidade crítica, proporcionando uma visão simultaneamente global e detalhada das tradições gramaticais lusófonas, uma vez que a obra demonstra que

> a Historiografia Linguística não pode ser apreendida de maneira estritamente objetiva, mas sim interpretada a partir de diferentes recortes e perspetivas. Nesse sentido, a escolha seletiva de temas e fontes documentais, como gramáticas, dicionários e leis educativas, possibilita-nos um olhar aprofundado sobre os processos de construção e transformação das normas linguísticas (p. IX).

Um vetor fundamental da presente coletânea repousa, em minha opinião, na sua estrutura comparativa. O arranjo dialético — Portugal/Brasil para cada tema — permite ao leitor observar simultaneamente continuidades históricas, divergências estruturais e dinâmicas próprias de cada tradição. O resultado passa por uma abordagem transatlântica rara, que contribui para romper fronteiras disciplinares e nacionais no estudo do pensamento linguístico-gramatical. A obra é particularmente útil para investigadores da Historiografia Linguística, estudiosos da gramaticografia portuguesa e brasileira e para docentes responsáveis por unidades curriculares de História da Língua Portuguesa e de Historiografia Linguística. A clareza expositiva, o rigor documental e a consistência metodológica garantem à coletânea um lugar de destaque na área.

A título de conclusão, poder-se-á afirmar que *História do Pensamento Linguístico-Gramatical em Portugal e no Brasil* é uma contribuição que consolida o diálogo entre duas tradições historicamente ligadas, mas nem sempre tratadas em conjunto. A meu ver, este estudo constituirá uma referência incontornável nas discussões sobre o pensamento linguístico no mundo lusófono, esperando vivamente que se cumpram os desejos dos editores quando afirmam na p. X:

O resultado que aqui apresentamos não pretende ser definitivo, mas sim um convite à revisão crítica e ao aprofundamento de estudos que deem continuidade a esta investigação sobre o passado, o presente e as perspetivas futuras da normatização da língua portuguesa.

Notas

[1] O projeto resultou da viagem de pesquisa e intercâmbio científico em Portugal dos organizadores brasileiros - Neusa Barbosa Bastos e Ronaldo de Oliveira Batista - e do apoio financeiro e/ou académico do Programa de Pós-Graduação em Letras da Universidade Presbiteriana Mackenzie (PROEX-CAPES), do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), do projeto PRINT-CAPES e do Colégio Doutoral Tordesilhas.

Inventions of a Present: The Novel in its Crisis of Globalization, by Fredric Jameson

Jeffrey Childs

Of all of the literary genres (with the exception of the perhaps now extinct literary essay), the novel is the most open to historical circumstance. This is no doubt structural: borrowing narrative from the epic, dialogue from drama, philosophical reflection from the essay, and the observation of daily life from journal writing, it has, since its modern invention in the seventeenth century, combined these in loose and highly varied constellations, sometimes challenging our ability to recognize the genre as such, with Pessoa's *Livro do Desassossego* (1982) representing perhaps the best challenge to date. It should thus come as no surprise that this genre would offer a privileged space of reflection for such an historically-minded critic as Fredric Jameson, as evidenced by one of the last collection of essays published in his lifetime: *Inventions of a Present: The Novel in its Crisis of Globalization* (2024).

Jeffrey Childs
Universidade Aberta, Lisboa, Portugal
Centro de Estudos Globais da Universidade Aberta, Lisboa, Portugal
0000-0001-7105-2260

Published in the year of his death, *Inventions of a Present* gathers together Jameson's scattered reflections on the novel ranging from his 1972 essay on the novel *Deliverance*, by James Dickey, to his 2022 essay on Ben Pastor's Martin Bora novels.

Fifty years of reflection on a literary form is significant span of time, and the diversity of Jameson's topics attests to the range of his interests and breadth of his imagination — a scope we (like Jameson himself) can now identify with "the global," beyond the more narrowly identified "globalization" in his title. Jameson's fluency with the heterogeneous vernaculars of the contemporary novel is impressive if not surprising, as he moves adroitly through such diverse phenomena as American regionalism, the Latin American "gringo novel" and magic realism, cyberpunk, the fallout of German reunification, the fragmentation of the former Soviet Union, late Japanese modernism, and the breakdown (and reconstitution) of the novel form in the recent television serial (namely, *The Wire*), among others.

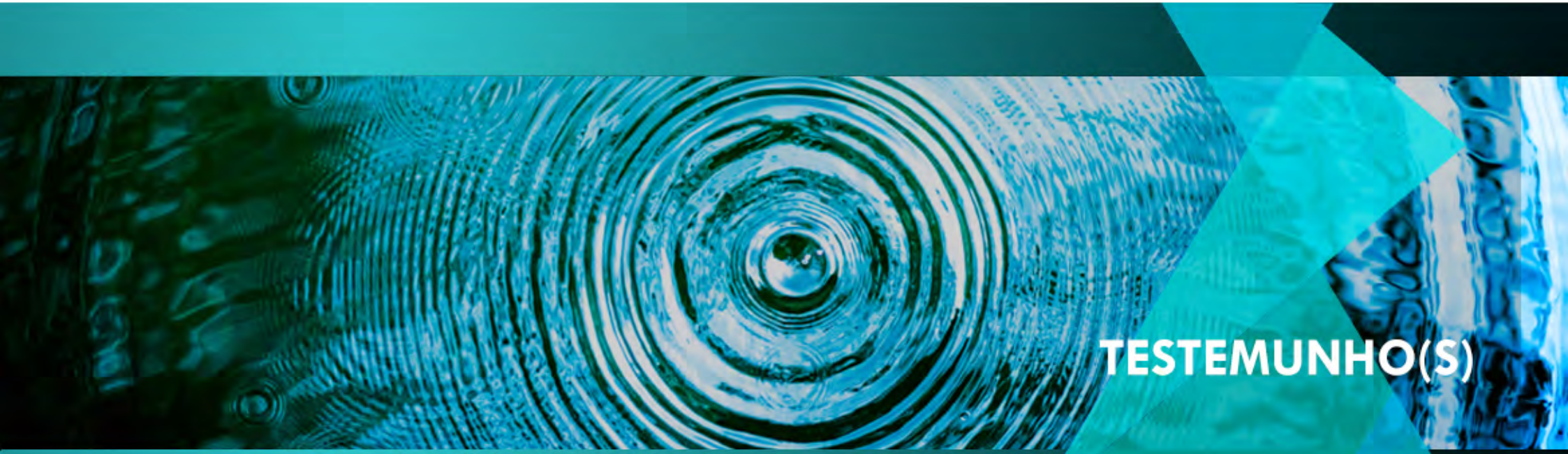
In many authors, such a diversity of topics would suggest a work of circumstance, indicative of the historical contingency of an author's work without a compelling organizing form or intention. Two overarching engagements save Jameson's work from this fate. The first of these is his extended meditation on the novel form, a form which develops in the nineteenth century to mediate the experience of lived reality and the typologies of the nation-state, yet which proceeds, in the twentieth century, to document the dislocation of the such centers of meaning through the expansion of the form throughout non-Western countries and the disruption of the individual as his/her own event horizon (a shift that can be charted within Jameson's work from the "form-problem" in Henry James to the conspiratorial novels of Delillo and Yurick). The second of these engagements is with globalization itself, the intensification and advancement of capitalism throughout the world. The central ambiguity of globalization — how does a process identified with the global as such advance per se? what

is the invisible center of its centrifugal operations? — lies at the heart of the contemporary novel, as Jameson notes:

> The dilemma can be schematically described as the increasing incompatibility — or incommensurability — between individual experience, existential experience, as we go on looking for it in our individual biological bodies, and structural meaning, which we can now ultimately derive only from the world system of multinational capitalism (2024, p. 65).

Of course, as with all things Jameson touches, the trick lies in the methodical patience with which he approaches this ultimate derivation. What makes his analyses so robust and compelling is that he is less interested in the absent cause of the historical circumstances he charts than in the dazzling prismatic effects it engenders as it is refracted through the lenses of particular aesthetic, sociological, and cultural formations.

At times it may seem as though Jameson is too beholden to the phenomena he analyzes, suffering (as it were) from a kind of cultural Stockholm syndrome (his remarkable work *Postmodernism; or, The Cultural Logic of Late Capitalism* [1984] is a case in point). Yet I think the larger message to be gleaned from his work is his genuine commitment to the cultural forms he analyzes, in this case the contemporary novel, not as finished cultural entities to be placed on the mantle of a global civilization, but rather as provisional mediations of objective material circumstances by human consciousness (whose own material form is, of course, language). For Jameson, cultural forms are never mere symptoms of the historical forces that shape them and make of them meaningful utterances. They are also the privileged locus in which such forces and meanings are refracted through human will, desire, and intelligibility, and returned to the world as something changed, perhaps even refreshed, accompanied by that thin sliver of human freedom we call hope.



TESTEMUNHO(S)

Prémio Armando Rocha Trindade

Conheci o Professor Armando Rocha Trindade em 1970, tinha eu 20 anos de idade, num café das avenidas novas, apresentado pela sua jovem mulher, Maria Beatriz, que havia sido minha professora de Metodologia das Ciências Sociais no ano anterior e com quem iria começar a trabalhar num projeto de investigação em Vale de Milhaços, concelho do Seixal, coordenado pelo professor João Pereira Neto e encomendado pelo saudoso urbanista professor Costa Lobo[1].

Descobrimos, nessa conversa, que ambos havíamos sido *meninos da Luz*, ainda que em anos diferentes, e que ele fora o comandante de Batalhão do seu curso. Como é tradição entre os ex-alunos do Colégio Militar, passámo-nos logo a tratar por *tu*, o que logo nos aproximou emocionalmente.

Para além disso, o que já não é pouco dada a consciência mútua de que partilhávamos os valores de camaradagem, lealdade, amor à verdade e responsabilidade cívica aprendidos no Colégio, percebemos que tínhamos muitos pontos de vista comuns sobre o país cinzento em que vivíamos, e sobre o muito que havia a fazer para lhe dar cor.

Iniciou-se aí, a partir dessa conversa à volta de uma bica, uma empatia imediata, sedimentando uma amizade que haveria de se manter ao longo dos 37 anos que convivemos, até ele partir precocemente.

Dada a ligação académica que tinha com a Maria Beatriz, que considerava minha mentora, fui-me mantendo em contacto com ele, seguindo com interesse e admiração a sua intervenção cívica nos anos seguintes à revolução, primeiro como Diretor Geral do Ensino Superior, depois como coordenador da Comissão de extinção do Ano Propedêutico (1977-1980), a que se seguiu a coordenação do IPED (Instituto Português de Ensino a Distância, 1979-1980), organismo que funcionou como viveiro da Universidade Aberta (UAb) que só haveria de ser criada 8 anos mais tarde.

Ao longo dos anos 80, como a Margarida (minha mulher) começou a trabalhar no IPED, fui acompanhando mais de perto as metamorfoses organizacionais que deram origem à criação da UAb em 1988 e à sua nomeação como primeiro Reitor.

Foi, no entanto, em 1989, que passei a conhecê-lo melhor, quando aceitei o seu convite para integrar a equipa da UAb como Coordenador de Ensino. Fi-lo essencialmente por razões políticas, convencido de que o projeto da UAb, à semelhança do que havia acontecido noutros países, poderia dar um enorme contributo para a democratização do acesso ao ensino superior sem perda de qualidade e, por consequência, para o desenvolvimento do país.

A dupla missão que me propôs era aliciante: por um lado, ajudar a criar padrões de atuação eficientes de modo a pôr de pé uma organização de ensino a distância que articulasse conteúdos de qualidade, com meios de comunicação educacional inovadores e com uma gestão rigorosa; por outro, e para que isso fosse possível, havia que construir uma equipa de raiz, a partir de um conjunto de jovens docentes recrutados de áreas científicas muito diferentes. Em suma, o desafio era construir uma equipa com forte coesão e com uma orientação coletiva sólida.

Aceitei o desafio com entusiasmo, convicto de que os valores colegiais que partilhávamos nos iriam ajudar na missão. Devo dizer que nunca me arrependi desta decisão: ao longo dos anos, mantivemos uma relação de confiança mútua extremamente sólida, assente no respeito pelos diferentes papéis que desempenhávamos, chefe e subordinado, numa relação de frontalidade total (sempre lhe disse o que pensava sem receio de suscetibilidades narcísicas da sua parte, na certeza de que a decisão final seria sempre dele) e da sua confiança ilimitada (por vezes, confesso, incómoda) nas minhas decisões.

Conto apenas quatro episódios para ilustrar a nossa relação:

— Lisboa, 1990 (junho): numa sexta feira à tarde, com o Reitor ausente em Aveiro numa reunião do Conselho de Reitores, a Vice-Reitora igualmente fora bem como a Administradora, a UAb foi invadida por cerca de 300 professores em fúria, ameaçando ocupar as instalações e danificar o equipamento. Alertado para a situação, consegui que os gritos se fossem transformando em palavras e que a multidão elegesse 10 representantes para falar comigo. Numa reunião entrecortada por telefonemas para o ART, que me ia dando orientações, escutei os representantes sindicais e transmiti as suas reivindicações, tendo-lhes assegurado após algumas negociações complexas (as duas Federações recusavam-se a dialogar uma com a outra), a realização de 2 reuniões na semana seguinte. Naquele clima de alta tensão, tive sempre a segurança de poder empenhar a minha palavra, pois me sentia legitimado pelo seu total apoio.

— Macau, 1995: uma manhã, ART chama-me e informa-me que precisava da minha ajuda para o substituir num seminário internacional sobre os estudos superiores em Macau, que iria decorrer dentro de poucos dias, para fazer uma comunicação sobre a nossa contribuição, em parceria com uma instituição de Hong-Kong, para a criação da Universidade Aberta Internacional da Ásia[2]. Aos meus receios inevitáveis respondeu que tinha completa confiança em mim, que preparasse a comunicação como entendesse e que ele a assinaria comigo se eu quisesse[3].

— Florianópolis, 1998: à semelhança do que se havia passado 3 anos antes, pediu-me para o substituir, à última hora, numa conferência internacional, desta vez no Brasil[4]. Apesar de lhe ter dado a comunicação previamente, para ele a poder corrigir, não só não o fez como insistiu para que a autoria fosse exclusivamente minha, apesar de ter sido ele o convidado.

— Luanda, 1996: após um pedido do bispo do Menongue à nossa embaixada em Angola, remetido pelo Ministério dos Negócios Estrangeiros à UAb, encarregou-me de fazer um parecer sobre a viabilidade de a UAb vir a apoiar um grupo de pessoas impedido de continuar os seus estudos superiores. Convém sublinhar que se estava em plena guerra civil e o Menongue estava sitiado pela UNITA, o que impedia quaisquer comunicações terrestres ou aéreas, à exceção das avionetas do Programa Alimentar Mundial (PAM) da ONU. Aprovado o meu parecer com entusiasmo, acompanhei-o com o então administrador Dr. Manuel Torres numa missão exploratória de 3 dias a Luanda, em condições de segurança precárias[5], a fim de obter a necessária luz verde das autoridades oficiais e desenhar uma estratégia local que possibilitasse fazer chegar os pacotes multimedia aos futuros estudantes. Convém recordar que ainda não havia internet e que o processo de ensino-aprendizagem era então feito através de pacotes multimedia com manuais, audiogramas e videogramas. Por seu turno, as comunicações entre os estudantes e a UAb tinham de ser feitas pelo telefone, o que no caso em questão era impossível, exceto para quem tinha telefone por satélite ou pela rede de rádio amadores das dioceses. A solução passou por uma parceria com o Conselho Episcopal de Angola, que passou a enviar o nosso material educativo nas avionetas do PAM. Em todo este complexo processo, senti o seu total compromisso com o projeto, sem o qual nunca poderia ter sido operacionalizado.

O Armando (permitam-me que o trate assim) era um Homem com H grande: leal, verdadeiro, criativo, humilde a reconhecer erros, com uma inteligência brilhante, um verdadeiro líder democrático, com um estilo de liderança suave, mas firme, que teve o condão de me pôr a render talentos que eu não conhecia. Sou, por tudo isto, suspeito ao falar dele, dado o tanto que com ele aprendi, não só sobre o ensino a distância, mas também sobre as boas práticas de relacionamento. Evidentemente que

ninguém é perfeito e o ART tinha algumas vulnerabilidades, como o de ser suscetível a abusos de gente oportunista. Mas isso são questões menores que se diluem na imagem que tenho dele como figura exemplar.

Foi um Físico brilhante, convertido por motivações democráticas a pioneiro e perito na área da educação a distância com reconhecimento mundial (foi dirigente de redes como a European Distance and E-Learning Network — EDEN — e de instituições como o International Council for Open and Distance Education — ICDE).

À nossa escala, foi um enorme privilégio tê-lo tido como Reitor-Fundador. Por isso, não posso acabar este testemunho pessoal sem elogiar a iniciativa de ter sido criado recentemente o Prémio Armando Rocha Trindade.

Deixou-nos precocemente. E faz-nos falta, apesar de continuar a ser uma referência incontornável na nossa memória quotidiana.

Por Hermano Carmo

Entrega do prémio Armando Rocha Trindade

Notas

[1] NETO, et al. (1971). **Vale de Milhaços Indicadores sociais para a urbanização de um loteamento clandestino do concelho do Seixal**. Lisboa: Instituto de Alta Cultura.

[2] Ele não poderia estar presente pois já se havia comprometido a fazer uma conferência na América Latina na mesma data, para uma rede internacional de ensino a distância.

[3] A comunicação conjunta acabou por se chamar *A Universidade Aberta Internacional da Ásia (Macau) na perspectiva do ensino a distância da região da Ásia-Pacífico*, publicada depois com versões em português e chinês nas Actas do seminário Internacional sobre O*s estudos superiores em Macau*.

[4] CARMO (1998). O modelo da Universidade Aberta (Portugal) e os novos paradigmas de EAD, Workshop sobre Telemática para a educação e desenvolvimento na Conferência sobre Ensino a Distância: paradigma de novo século, Florianópolis, Santa Catarina.

[5] Durante os 3 dias de estadia, fomos sempre acompanhados por seguranças, pois o risco de assaltos era elevado. Por outro lado, no mês anterior tinha-se registado um surto de cólera em Luanda, pelo que as preocupações sanitárias eram enormes (e.g. tivemos de lavar os dentes com água do Luso). Mesmo assim, voltámos a Lisboa todos com desarranjos intestinais…

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