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RESEARCH ARTICLE

The vulnerability of Central Africa's estuarine population to forest degradation and coastal erosion

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ABSTRACT
This study investigates how marginalized populations in Central Africa are affected by environmental degradation and coastal erosion, particularly at the Wouri estuary. Understanding these effects is crucial for vulnerable communities. The research employs a mixed-methods approach, combining geospatial analysis of coastal erosion with surveys of residents to assess vulnerability factors and their impact on quality of life. Findings show significant ecosystem decline, with the Atlantic forest decreasing by 5.5% and mangroves by 9.5% between 1986 and 2018. Coastal erosion affects 41.7% of the estuary's coastline, with a maximum retreat of −20.75 m/year at Cape Cameroon, corresponding to a retreat of around 933.75 m over 45 years (1975–2020). These environmental shifts are not just physical; they impact people directly. Approximately 30% of surveyed residents reported damage to their homes from flooding, and many lack reliable access to basic services. The study suggests implementing specific public policies to help communities better withstand environmental challenges, including awareness initiatives on sustainable management. Key insights highlight the importance of integrated coastal management that includes local knowledge. Evaluating socio-economic impacts through geospatial and qualitative data is essential, alongside evidence-based policies to strengthen

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Coastal erosion; environmental degradation; marginalized population; vulnerability; Wouri estuary; Africa

1. Introduction

There is increasing worry about how disadvantaged populations are affected by environmental degradation and coastal erosion, particularly in Africa, where the effects of climate change are exacerbating socio-economic challenges. According to Adger et al. (2021), vulnerable communities are often the most affected by extreme climate events, due to their dependence on natural resources and the lack of adequate infrastructure. Additionally, coastal erosion poses a significant threat to many coastal regions, leading not only to the loss of agricultural land but also to devastating impacts on natural habitats (Kaczan & Orgill, 2020). The Wouri estuary in Cameroon serves as a relevant case study,

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illustrating the concrete impacts of these phenomena on local populations. By integrating multidisciplinary approaches, this research aims to better understand the dynamics of vulnerability and to propose adapted solutions to strengthen the resilience of affected communities across Africa.

Coastal erosion is a global issue (Saengsupavanich et al., 2023), but it is particularly critical in Africa (West and Central) (Niasse et al. (2004). Its management has become central focus in academic and policy debates. Many African universities from Cameroon to Gabon now offer courses on coastal erosion. The region's vulnerability to coastal erosion, highlighted by record recession levels, has prompted initiatives such as the World Bank's WACA program, the Cameroon's National Development Strategy (MINEPAT, 2020), which prioritizes coastal protection, and the UEMOA'sregional coastal erosion control program (UEMOA, 2007). Population growth and economic development exacerbate these coastal and environmental pressures. Mangrove forests, which are crucial for coastal protection, are in decline (Bocquet & Tech, 2018; Bojang & Ndeso–atanga, 2009). Although Cameroon houses 6% of Africa's mangroves (UNEP, 2007), they face threats. Coastal erosion, intensified by mangrove loss, is severe (Ovono, 2017).

Environmental degradation in Africa is a growing problem that seriously impacts the continent's economic and social development. UNEP (2021) states that environmental changes are occurring at an alarming rate, significantly affecting air quality, access to fresh water, and land degradation. According to the FAO (2018), around 500,000 square kilometers of degraded land in Africa are affected by erosion, salinization, and deforestation, compromising food security and nutritional health. Furthermore, the illegal wildlife trade threatens biodiversity and the economic and social stability of affected regions. In the face of these challenges, African governments must adopt sustainable natural resource management strategies and strengthen intergovernmental cooperation to address these environmental issues effectively.

In Cameroon, studies have investigated coastal erosion's impact on local populations, including Ellison and Zouh (2012), Ondoa et al. (2018), and Fossi Fotsi et al. (2019). Research has also focused on mangrove cover dynamics, with Kana et al. (2019) using remote sensing to map land use in the Wouri estuary. Others have assessed mangrove loss in the Douala-Edéa Faunal Reserve (ASD, 2015) and linked degradation to climate change (Joanna & Zouh, 2012). The Wouri estuary, a 1200 km^2 area with complex coastal dynamics and a large mangrove forest (Ellison & Zouh, 2012; Fossi Fotsi et al., 2023; Mbevo Fendoung et al., 2017), is home to the rapidly growing city of Douala, with significant environmental impacts (BUCREP, 1976, 1987, 2005; NIS, 2019). Population growth in the estuary correlates with mangrove degradation.

The Wouri estuary (Figure 1), a micro-tidal environment with a 1.7–2.8 m tidal range (Ndongo et al., 2015; Ondoa et al., 2018), is influenced by four major rivers- the Moungo, Wouri, Dibamba, and Sanaga- which have shaped the estuary into five distinct zones with varying bathymetry. Mangrove areas and specific study sites are indicated, featuring a central ebb channel and submarine sedimentary prism (Fossi Fotsi et al., 2023). Longshore drift, a south-to-north current, drives sediment transport along the Cameroon coast (Ondoa et al., 2018). This research focuses on Manoka and Cape Cameroon, with 8,000 and 4,000 inhabitants, respectively (BUCREP, 2010; Mbevo Fendoung, 2019), because they rely on the mangrove ecosystem and face intense

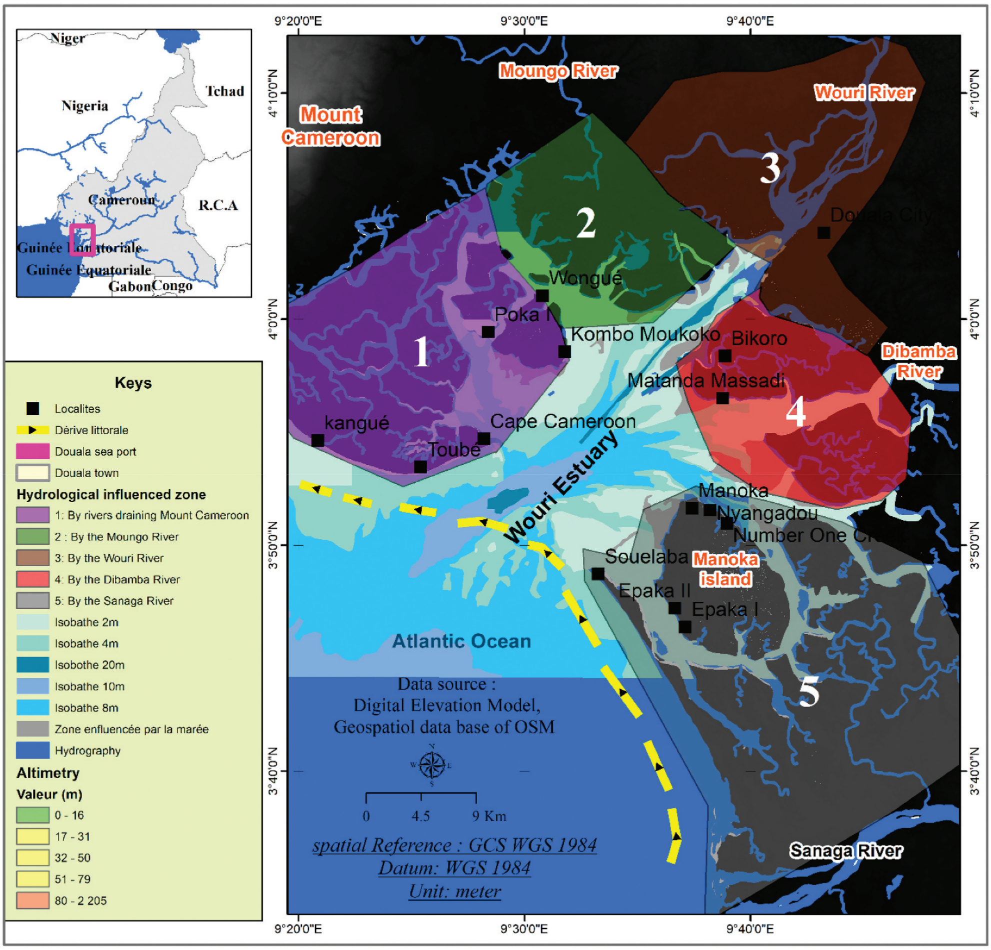

Figure 1. The case study area, located in the Wouri estuary. Source: designed by the authors.

human pressure, climate change, and high vulnerability (Din et al., 2008; Dzalla Ngangué, 2013; Fongnzossie, 2014; Tatuebu Tagne et al., 2022). The study uses remote sensing, GIS, and field data to analyze coastal dynamics, environmental degradation, vulnerability, and hazard perception.

2. Theoretical underpinning of the research

Human economic activities are at the core of most global environmental problems, including ecosystem degradation, and coastal issues such as pollution, erosion, and biodiversity loss which in turn impact human life (Emmanuel, 2005). In Cameroon, particularly in Douala, Kribi, and Limbé, mangrove ecosystems face significant threats due to agro-industry, industrial-port infrastructure, and rural-urban migration.

The theory of social management of ecosystems, resources and the environment, as proposed by AgroParis Tech (2014), underlines that environmental problems stem from societal structures. It shifts the research focus to the societal causes of environmental degradation. Given the environment's static physical nature, human activities are the primary drivers of change. This perspective is exemplified by African mangrove ecosystems, once considered hostile but now degraded due to increased human presence and activities.

The open and accessible nature of resources inevitably leads to competition. In the case of mangroves, this competition has resulted in deforestation and degradation, particularly evident in Cameroon's coastal zone. Multi-nationals and public authorities engage in poorly regulated resource sharing, which leads to the mention of Garrett Hardin's 'tragedy of the commons.' leads to mention once again Garrett Hardin's 'tragedy of the commons.' As exemplified by Manoka fishermen, individual rational behavior (increasing fishing lines) can lead to collective irrationality (resource depletion).

Nonetheless, Hilhorst (2004) insists on the reciprocity and complexity of drivers. Vulnerability and hazard analysis in coastal zones must consider both physical and human factors, as human activities influence hazard occurrence (Magnan, 2009). Examples include coastal erosion exacerbated by human interventions such as the Akossombo dam's impact on the Togolese coast (Rossi, 1989). Globally, greenhouse gas emissions (IPCC, 2007) contribute to rising sea levels, complicating risk reduction strategies. Environmental challenges disproportionately affect poor people (Ravallion, 1996).

3. Materials and methods

3.1. The study area

Central Africa is characterized by extensive coastlines, particularly along the Atlantic Ocean, where coastal erosion and environmental degradation pose major challenges. According to Kouadio et al. (2021), this region, rich in biodiversity, is experiencing increasing pressures due to urbanization, resource exploitation, and the effects of climate change, leading to increased vulnerability of coastal populations. The spatialization of these phenomena reveals particularly affected areas, where land loss and degradation of marine ecosystems threaten local livelihoods (Yao et al., 2022). Thus, it is crucial to map these impacts to develop adaptation and sustainable management strategies to protect the environment and vulnerable communities across Africa. This research employed a case study approach to grasp the complexity of the local context, including human and physical drivers of the evolution of an urban estuary landscape in central Africa.

This study employs a multifaceted methodological approach. For the Wouri estuary case study, fieldwork was conducted. Continentally, the analysis relied on a literature review and databases like the Global Land Cover Facilities (GLCF). Methods included remote sensing/GIS for satellite image analysis, oral surveys for household vulnerability assessments, and the landscape approach, utilizing Socio-Economic Ecological Production Landscapes (SEPLs) to examine local perceptions of environmental change.

3.2. Remote sensing/GIS approach

To assess land degradation and urbanization expansion in the Wouri estuary, we generated land use maps using Landsat imagery (1986, 2000, and 2018) and the GLCF database. We performed a supervised maximum likelihood classification (Sisodia et al., 2014; Ouchra & Belangour, 2021). Due to the spectral similarity between mature agro-industrial plantations and Atlantic forests, the 2018 classification was manually corrected in ArcMap 10.5. The annual degradation rate was calculated based on forest disturbance using the method of Kamungandu Musampa et al. (2012).

$$\mathbf{ADR} = \frac{\frac{S2}{S1}}{t} * 100 \tag{1}$$

with S1: initial forest area; S2: area of forest lost; ADR: annual rate of degradation (%); t: number of years between two dates.

Coastal erosion in the Wouri estuary was mapped using Landsat and Pleiad/GE images and DSAS software. Landsat imagery (1975, 1986, 2000, 2016, 2020) was pre-processed (Erdas Imagine 2014®) and analyzed to determine the mangrove coastline. The microtidal Wouri estuary minimized tidal impacts on coastline mapping. Coastline delineation was automated and manually corrected (Anders & Byrnes, 1991). DSAS V.5 calculated erosion, accretion, and stability rates (Himmelstoss et al., 2018). Changes were expressed in meters per year, with > 5 m/yr indicating accretion and < −5 m/yr indicating erosion. The End Point Rate (EPR) method was used (Himmelstoss et al., 2018), with a 5 m uncertainty margin (Baig et al., 2020).

The total pixel error (Ea) was computed for 1975–2020, combining shoreline position, measured transect (Em), and annualized errors. The resulting Ea value of 0.5 is found.

$$\boldsymbol{Ea} = \frac{\sqrt{\mathrm{Et1}^2 + Et2^2 + Et3}}{\mathrm{Total\ period(years)}} \tag{2}$$

Coastal erosion was mapped using 50 m spaced transects (500 m length). Coastlines were extracted semi-automatically with ArcMap 10.5®, refined manually, and analyzed using DSAS V5 to quantify shoreline change. A prospective DSAS V5 analysis estimated coastline dynamics until 2038.

3.3. Social science approach

A social approach was used to assess vulnerability in 70 households on Manoka Island and the Cape Cameroon peninsula. Two questionnaires evaluated vulnerability by examining exposure, sensitivity, and adaptive capacity to 12 identified hazards. Adaptive capacity was assessed through strategies like education, food security, climate change awareness, housing quality, and diversification.

The second questionnaire, adapted from the Satoyama Initiative (Bergamini et al., 2013), analyzed socio-ecological production landscapes (SEPLs) through four themes (Figure 2): ecosystem protection, agricultural biodiversity, knowledge, and social equity (2016). This aimed to understand landscape change in relation to local communities and ecological sustainability (Tchindjang et al., 2015). Challenges like flooding, windstorms, and pollution (marine, river, and air) are influenced by factors such as rainfall patterns (Tchindjang, 2013), wind dynamics (Keugne Signe, 2018; Morin & Kuete, 1988), and industrial activities.

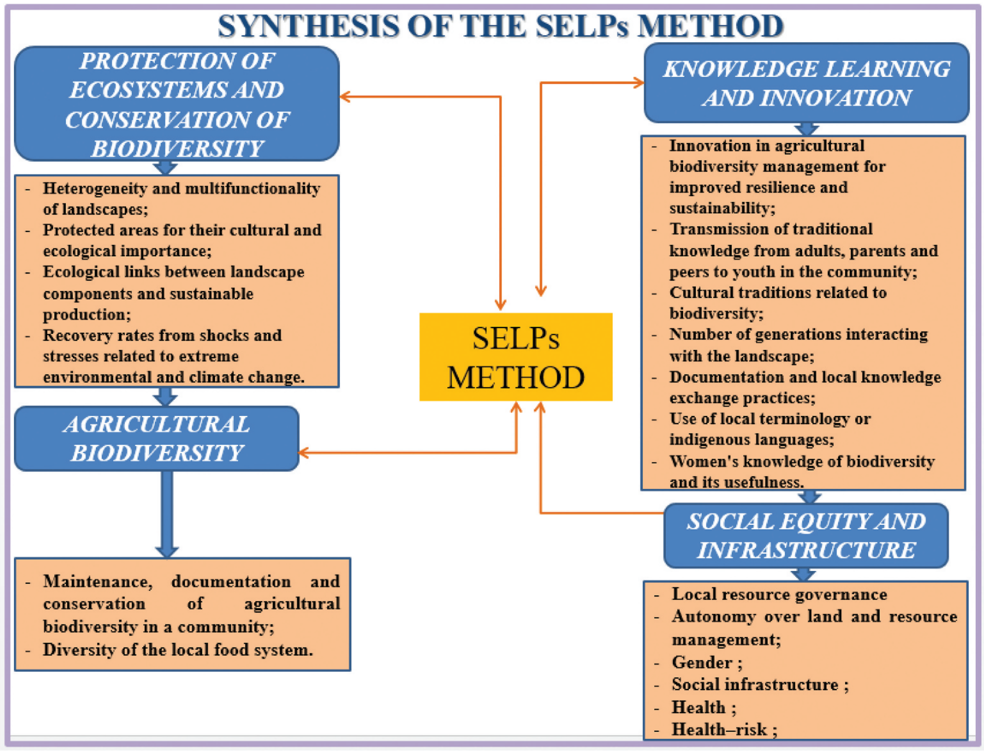

Figure 2. SELP method applied to the fisherman communities of the Wouri estuary living in the mangrove forest. Source: designed by the authors.

A guide was adapted for Cape Cameroon and Manoka islands to balance mangrove and littoral forest use with conservation. Mangroves provide coastal protection, biodiversity, and carbon storage while supporting local livelihoods. The Socio-Ecological Landscape Production (SELP) approach aims to reconcile these needs (Bergamini et al., 2014). Twenty-four participants from preacher communities engaged in the SELP exercise, scoring local perceptions of landscape change across four themes.

4. Results

4.1. Dynamics of the plant cover

The Wouri estuary, spanning approximately 1200 km^2 across Douala 1, 4, 5, 6, Mouanko, and Dizangué, is a heavily modified environment. Land cover is categorized into buildings, bare soils, intact/degraded forests, mangroves, and agricultural lands (Figure 3).

The urban category is critical due to Douala, Cameroon's largest city in the Wouri estuary, which is experiencing significant population growth. Between 1986 and 2018, urban expansion increased buildings and bare ground by approximately 187 ha/year. Although growth slowed after 2000, it resumed in 2015, leading to reduced infiltration and increased flooding (Bruckmann et al., 2019; Mbaha & Tchounga, 2020). Land use transformation, especially the loss of mangroves on Douala's southern and western sides,

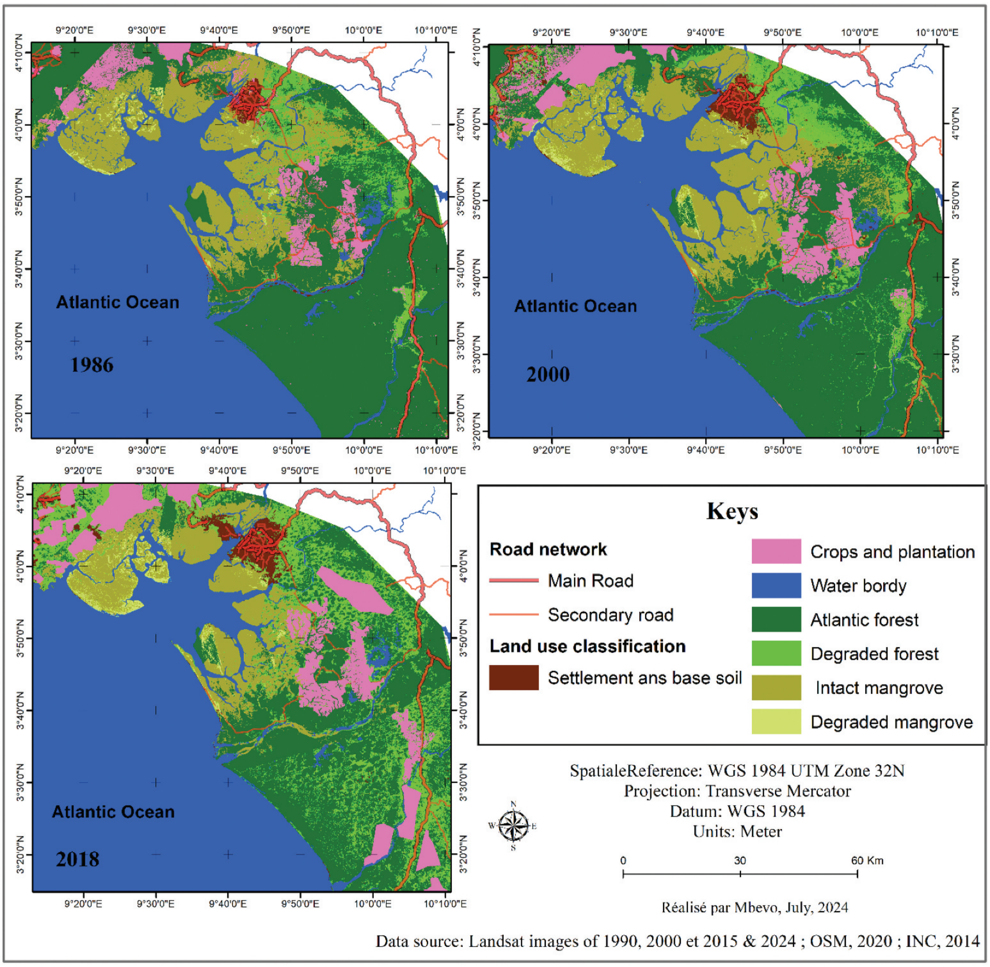

Figure 3. Evolution of land cover in the Wouri estuary between significant decline. Source: processing of Landsat satellite images from 1986, 2000 and 2018.

has severe consequences. By 2018, about 43 ha of mangrove forest had been converted to bare land or agro-industrial plantations, exacerbating coastal erosion and flooding.

The analysis of land cover changes indicates that mangroves were already showing signs of degradation in 1986. This degradation is driven by local populations in Douala exploiting mangrove wood for cooking and firewood (Din et al., 2008) and by illegal exports to Nigeria, particularly by expatriates from Nigeria and Mali occupying the estuarine islands (Kengne Fodouop, 1988). From 1986 to 2018, the primary littoral forest regressed at a rate of 656 ha/year, while intact mangroves declined by 2 ha/year, resulting in 708 ha/year of degraded mangrove. The Atlantic forest faced a degradation rate of 5.5%, and intact mangroves experienced a degradation rate of 9.5%, leading to an overall annual degradation rate of 7.5%.

Initial pockets of degradation were concentrated in the northwestern part of the estuary, particularly around the Autonomous Port of Douala (PAD) and northeast of

Manoka Island, a historically exploited area for mangroves. During the colonial era, a timber exploitation company operated on Manoka Island (SNC-BOIS), but forest cover stabilized after its closure in 1972. Post-1986, however, mangrove degradation accelerated, and by 2000, environmental degradation had intensified, extending throughout the estuary by 2018.

Another important aspect is the presence of agricultural land and plantations surrounding the estuary. These plantations, mainly reclaimed from the littoral Atlantic forest, have significant economic importance (Ndjogui et al., 2014). Oil palm plantations began around 1907 under German colonization, particularly in the Edéa region. The Cameroonian government has promoted oil palm cultivation since 1963, leading to substantial exports through Douala Port, approximately 450,000 tons in 2020 (ECOFIN, 2020; INVESTIR AU CAMEROON, 2022). Paradoxically, palm oil imports into Cameroon remain significant (Miaro et al., 2021). Mapping indicates a slight increase in agro-industrial plantations from 1986 to 2018, averaging 116 ha/year.

These plantations facilitate soil erosion and may increase sediment loads in the estuary, particularly in the northwestern region near Mount Cameroon. The steep slopes and vulnerable geological conditions enhance natural erodibility, further exacerbated by ongoing environmental degradation (Moto, 2016). In summary, urban expansion and agricultural practices critically impact the Wouri estuary, leading to significant ecological challenges, including mangrove loss, increased flooding, and coastal erosion.

4.2. Coastline evolution

Landsat images (1975–2020) reveal significant erosion of the Wouri estuary coastline, particularly around Cape Cameroon. Analysis of 4713 transects shows 41.7% erosion, 39.3% stability, and 19% accretion. For a detailed study, the estuary is divided into 5 hydrodynamic zones.

Zone 1 is under the influence of the Mount Cameroon watershed (Figure 4), this area is experiencing significant erosion. An average recession of −3 m/year has been measured, with occasional retreat reaching −20.75 m/year at the tip of Cap Cameroon. A value of −25.8 m/year was calculated between 2000 and 2022 at the Cape Cameroon point by Marie et al. (2023). This is the most erosive point in the Wouri estuary. According to previous statistics, in 45 years (1975–2020), this point has retreated by 933.75 m. However, limited accretion is occurring near Kapinta and Dengdé. The island of Kombo Moukoko undergoes minor erosion (−0.1 m/yr) at Wongué, contrasting with accretion (+1.3 m/yr) near the ocean and Koudoué. Zone 1 underwent a tidal inlet reorganization, shifting from a large SE-oriented inlet to a new SW-oriented one, which, along with a south-oriented inlet near Kombo Moukoko island, impacted sediment supply to shorelines, causing increased erosion near Cape Cameroon compared to other Zone 1 areas.

Zone 2, a delta-like formation influenced by the Moungo River (Regnault, 1987), is characterized by a high sediment supply (46.5 mg/l) (Ndam Ngoupayou et al., 2007). Despite mangrove degradation, this sediment input contributes to shoreline stability. Erosion (−0.1 m/year) is prevalent in northern Wongué, while accretion (+1.3 m/year) dominates the ocean-facing tip and Koudou.

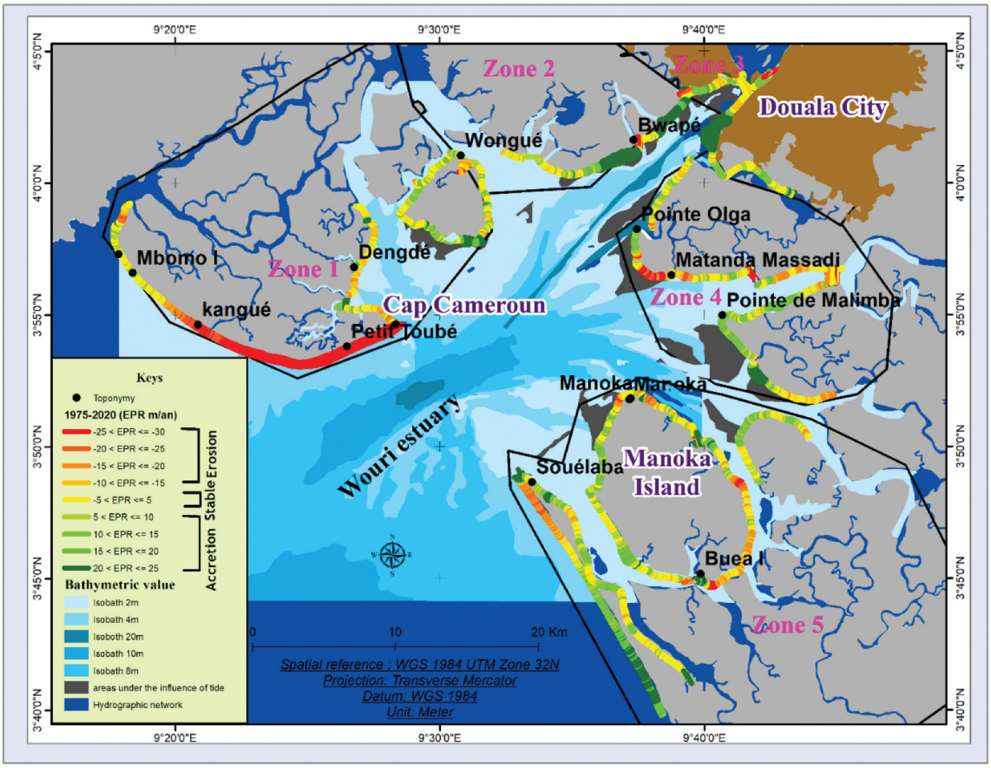

Figure 4. Coastline dynamics in EPR (m/year) between 1975 and 2020 in the Wouri estuary. Source: produced by the authors using coastline data extracted from Landsat.

Zone 3, primarily composed of the Wouri River, is undergoing rapid urbanization. This area exhibits a high accretion rate (+4.2 m/year), particularly on the river's banks, due to extensive backfilling by the port of Douala. While the river's sediment supply is unknown, the ongoing urbanization within the estuary, replacing mangrove forests, likely increases sediment input. This trend aligns with Douglas (1996) findings on tropical urbanization's significant sediment yield. As Douala expands, construction activities further contribute to sediment accumulation in the estuary.

Zone 4, influenced by the Dibamba River, shows significant coastal erosion south of Matanda Massidi, reaching −1.5 m/year on average. However, the area around Bwapé is accreting at 1.8 m/year due to the river's high sediment supply, despite deforestation. Sand extraction near Douala reduces this supply, requiring quantifying the river's sedimentary budget to understand its impact on coastline changes.

The coast of Zone 5, influenced by the Sanaga River, displays varied behavior. The northeastern tip accretes rapidly while the rest gradually retreats, except for localized accretion near Manoka Island and the southern part of Souélaba Spit. Zone 5, around Manoka island, is strongly influenced by the Sanaga River. Despite its large flow and sediment load, the Sanaga primarily feeds the estuary during exceptional floods via the Kwakwa channel. This impacts both the inner part of Zone 5, through direct sediment supply, and the outer part, through longshore

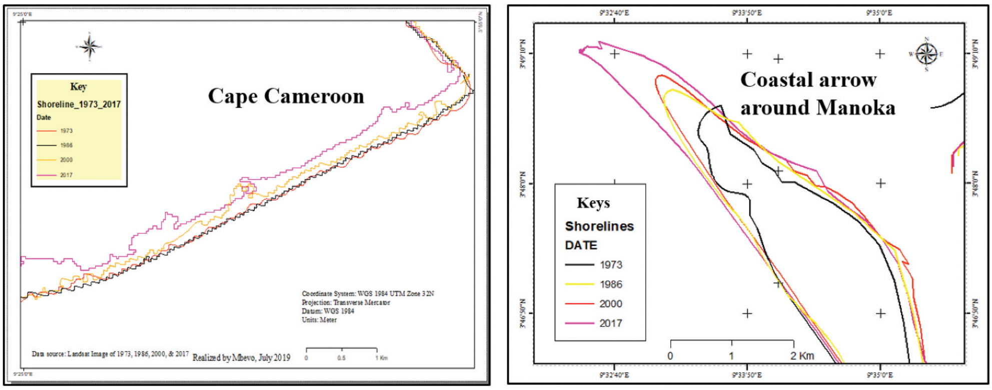

Figure 5. Progressive dynamics of the coastline around the Manoka spit and regressive dynamics in Cape Cameroon between 1975 and 2020. Source: classification of Landsat images.

currents transporting sediments from the Sanaga delta. While deforestation and agro-industries increase sediment supply to the Sanaga, numerous dams have a negative impact.

High erosion at Cape Cameroon is exacerbated by: (i) Mangrove destruction from local population needs and illegal logging. (ii) Deactivation of the main tidal channel, increasing water depth, reducing wave attenuation, and enhancing storm erosion (Figure 1). (iii) Changing coastal orientation, amplifying longshore transport and erosion (Figure 5). (iv) Northward migration of the Souélaba Spit (Morin & Kuete, 1988).

4.3. Analysis of the vulnerability of the island populations of Cape Cameroon and Manoka

4.3.1. Characteristics of island populations and highlights of their vulnerability

The population of Manoka commune is predominantly foreign, with Nigerians comprising 80% of surveyed households. The remaining population mainly comprises Cameroonians (Bamiléké, Bassa, Eton, Beti, Bulu, and Sawa), but with low educational levels. Over 80% have completed at most primary school. Income is low, and over 70% struggle to cover basic expenses.

The local economy relies on fishing and illegal mangrove exploitation, with declining fish stocks increasing economic hardship. Subsistence farming has emerged on Manoka island (Bojang & Ndeso–atanga, 2009) but is hindered by soil salinization in Cape Cameroon. Groundwater is brackish, forcing reliance on rainwater collected in rudimentary systems (Figure 6). Developed water sources are scarce. Over 37% of the population uses untreated water from undeveloped sources, while 46% depend on water transported by canoe from Douala or Tiko.

High water costs and limited mobility exacerbate the population's vulnerability. During the dry season, water scarcity due to salinization forces residents to import water from Douala at a significant cost (G. N. Ajonina et al., 2015). Moreover, transport costs within the estuary are high, limiting movement for most residents.

Figure 6. Traditional rainwater harvesting system in Cape Cameroon (photo credit: mbevo, April 2019).

Health risks further compound the situation. The rainy season brings frequent floods and increased malaria, typhoid, and cholera cases (Mbevo Fendoung, 2019). Poor waste management and lack of sanitation infrastructure contribute to these health issues.

The Wouri estuary's remote islands, inhabited primarily by Nigerians, are largely neglected by the Cameroonian state. Civil servants assigned to the area are often absent, hindering disaster response. The 2010 Cape Cameroon floods (His Majesty Muléma, personal communication), resulting in fatalities and destruction, exemplify this. Despite a national contingency plan, its implementation is hampered by funding shortages, government inefficiency, and corruption.

The Douala-Edéa National Park, a valuable ecosystem, is also mismanaged. Lack of eco-guards, weak local enforcement, and illegal logging have degraded the park. Local communities suffering from marine intrusion and limited livelihood options negatively perceive environmental protection.While traditional authorities, such as the canton chief in Cape Cameroon, play a role, their power **is** limited. Ineffective public policies compound the state's absence. Unlike Congo, Burkina Faso, and Burundi, Cameroon has struggled to implement successful regionalization and healthcare programs. Madagascar (URUV (2015) and Benin (Eco-Bénin) offer examples of mangrove restoration through government-NGO partnerships, highlighting the potential for effective environmental management.

Overall, the Wouri estuary exemplifies the challenges faced by coastal communities in Africa: weak governance, environmental degradation, and limited livelihood opportunities.

4.3.2. Analysis of vulnerability profile to natural hazards

Our survey assessed local perceptions of natural hazards (Figure 7). Coastal erosion, flooding, and sea level rise were top concerns for 35% of households. In Cape Cameroon, these hazards are severe, with 123 houses destroyed and over 615 people relocated (Tataw

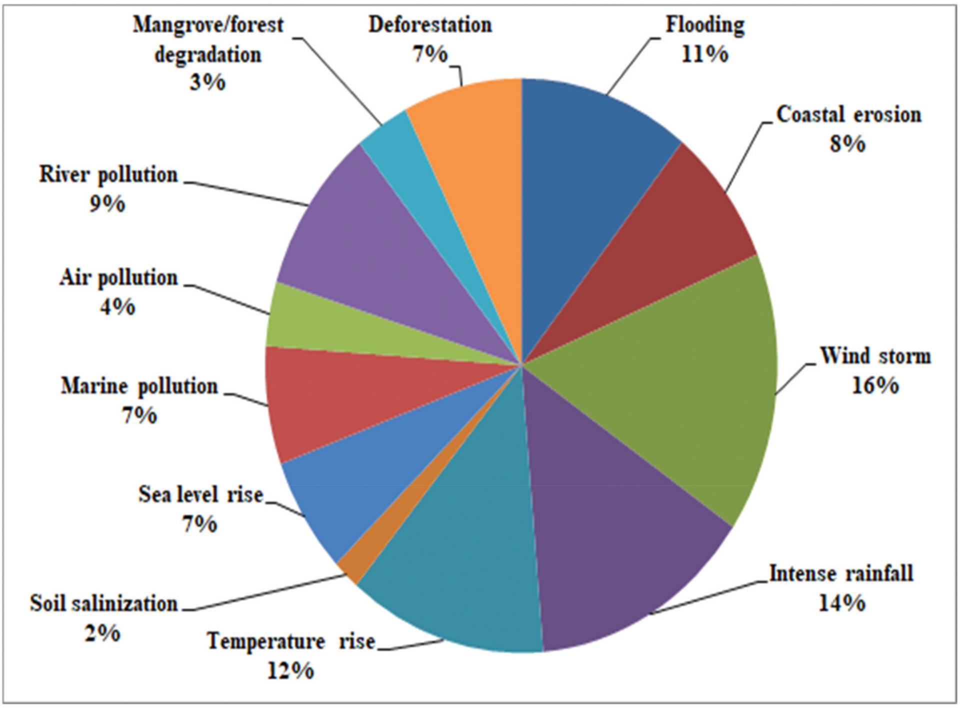

Figure 7. Population perception about the most important hazard affecting them, based on the questionnaire, exposure, sensitivity, and adaptation capacity is evaluated as explained in the section material and method for households in Manoka island and Cape Cameroon to evaluate possible differences.

et al., 2021). Overall, 38% of respondents believe hazards significantly impact their lives. Forest destruction strongly affected 10%, highlighting the link between environmental degradation and local communities. While salinization and marine/river pollution are less severe, they still impact health, especially for children, elderly, and women, due to waste and sewage.

Both Manoka and Cape Cameroon exhibit similar exposure to various hazards, including intense rainfall, rising sea levels, flooding, windstorms, and mangrove/forest degradation (Figure 8a). However, Manoka is more sensitive to beach resources, fishing, accommodation, and mangroves (Figure 8b). Conversely, both localities have low adaptive capacities, primarily due to low education levels, limited food self-sufficiency, and poor habitat quality (Figure 8c). While Manoka's vulnerability is slightly lower than Cape Cameroon's, both areas face significant challenges, particularly coastal erosion, flooding, and salinization (Figure 8d).

4.4. Perception of environmental degradation

We examined local perceptions of environmental change in the Manoka area and Cap Cameroon peninsula using Socio-Ecological Production Landscapes (SEPLs) analysis (see Materials and Methods).

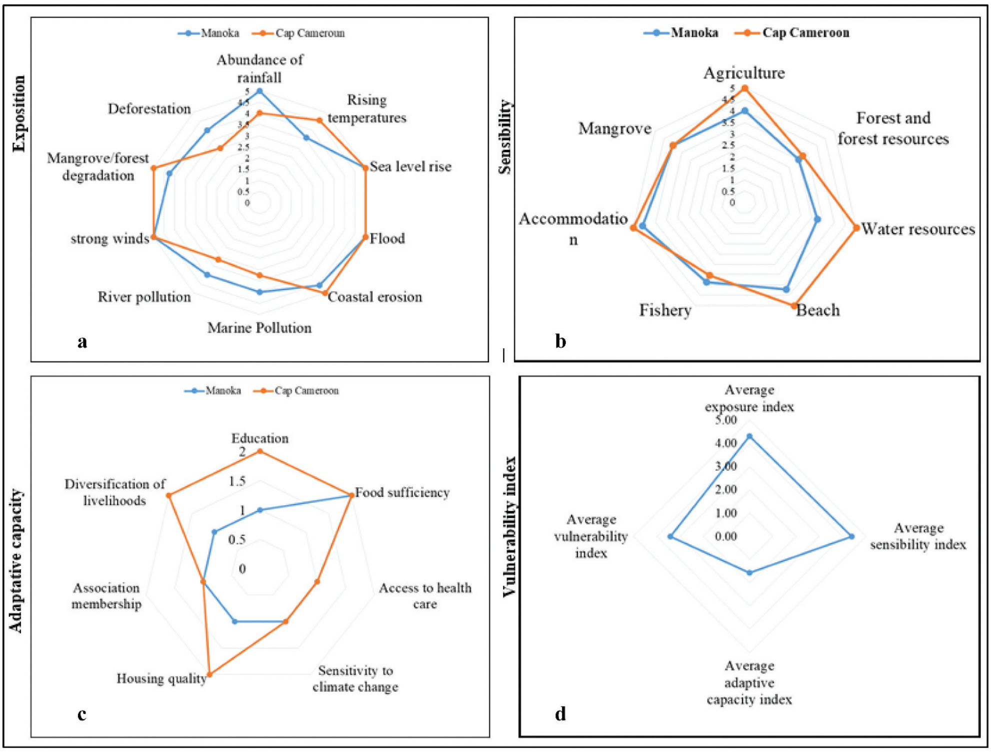

Figure 8. Summary of sub–indices and vulnerability indexes. Produced by the authors using field investigation data collected in Manoka island and Cape Cameroon.

Manoka residents perceive landscape quality as above average (3.37/5), though ecosystem protection is lowest (2.43/5), reflecting mangrove destruction evident in Figure 3. Agricultural biodiversity scores well (3.2/5) due to thriving subsistence farming. Governance and social equity are strong (4.23/5), with traditional authority prevailing over the state. Knowledge and innovation are high (3.99/5), likely due to NGO interventions (CWCS, ASD . . .). While degradation exists, resources support living conditions above minimum levels (Figure 9a).

In Cape Cameroon, overall perception is slightly above average (2.9/5), with disparities between indicators. Ecosystem protection is low (2.47/5) due to anthropogenic and natural pressures. Agricultural biodiversity is also low (2.19/5) due to salinization. Conversely, knowledge and innovation (3.64/5), governance and equity (3.36/5), and livelihoods (2.97/5) are strong (Figure 9b). Coastal erosion and flooding drive adaptation efforts and a strong community consensus. Despite absent state support, traditional leadership and a local vigilance committee contribute to resource governance and social equity. Livelihoods diversify through fishing and NTFPs.

The analysis of standard deviations in Table 1 reveals varying levels of consensus among populations on SELP dimensions. Overall, opinions diverge across modalities and locations (Cape Cameroon, Manoka). According to the standard deviation (SD) value (SD: 0.75 Manoka, 0.70 Cape Cameroon), ecosystem

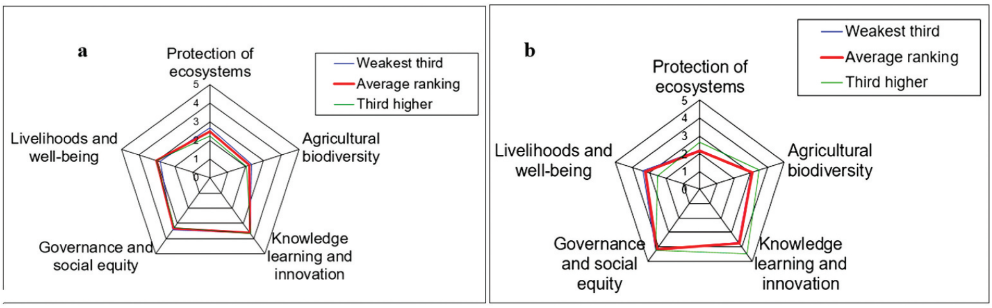

Figure 9. Perception of environmental changes by the people of Manoka (16a) and Cape Cameroon (16b). Source: produced by the authors, using field investigation data.

Table 1. Summary of the scores of the SELP exercise of the island populations at Manoka and Cape Cameroon sites. Source: produced by the authors, using field investigation data.

Statistics	Area	Protection of ecosystems	Agricultural biodiversity	Knowledge learning and innovation	Governance and social equity	Livelihoods and well–being
Weakest third	Manoka	2.22	3.04	3.69	4.25	3.38
Average ranking		2.17	3.07	3.78	4.19	3.22
Third higher		2.63	3.50	4.50	4.25	2.50
	Mean	2.43	3.2	3.99	4.23	3.03
Weakest third	Cape Cameroon	2.69	2.34	3.63	3.44	2.84
Average ranking		2.48	2.19	3.63	3.36	3.04
Third higher		2.25	2.04	3.68	3.29	3.03
	Mean	2.47	2.19	3.64	3.36	2.97
Standard deviation	Manoka	0.75	0.52	0.79	0.89	1.59
	Cape Cameroon	0.70	0.65	0.44	0.27	0.78

protection exhibits low consensus in both areas. Conversely, agricultural biodiversity consensus is higher (SD: 0.5 Manoka, 0.6 Cape Cameroon), reflecting its low priority. Fishing remains the primary activity. Knowledge acquisition consensus is low in Manoka (SD: 0.7) but high in Cape Cameroon (SD: 0.4), linked to the decline of Douala-Edea National Park and Cape Cameroon's emerging economic role. Governance and social equity consensus are low in Manoka (SD: 0.8) but high in Cape Cameroon (SD: 0.2). Manoka's population holds mixed opinions on governance due to the park's decline despite NGO interventions. While the Mabé mangrove reserve faces similar challenges, Cape Cameroon benefits from stronger traditional authority. Livelihoods consensus is very low in Manoka (SD: 1.59) but higher in Cape Cameroon (SD: 0.78). Cape Cameroon's population unanimously agrees that land degradation/salinization hinders farming, while Manoka practices subsistence agriculture amidst land access constraints within the national park.

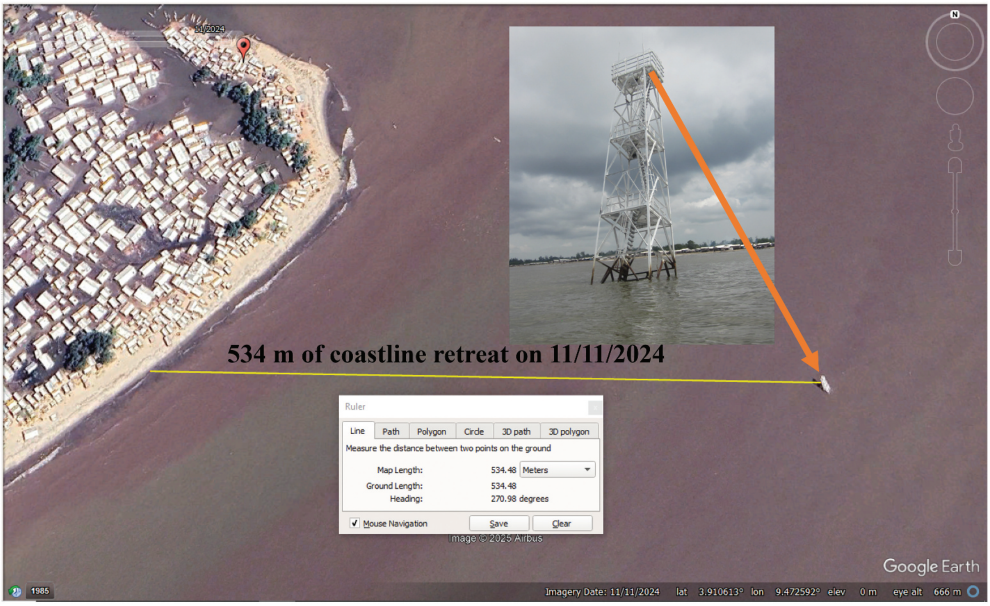

Figure 10. Further evidence of the rapid retreat of the coastline at Cap Cameroon. Source: aerial photo of 11/11/2024 posted in Google earth.

5. Discussion

5.1. Coastal erosion/dynamic in Central Africa and along Africa Atlantic coast

Coastline dynamics in the Wouri estuary are shaped by both natural and anthropogenic factors. Remote sensing reveals significant coastal erosion, particularly around Cape Cameroon Peninsula, with rates of up to 10 m per year. This issue is exacerbated by mangrove degradation, which is crucial for coastal protection (Ellison & Zouh, 2012). Rapid urbanization and illegal resource exploitation increase flooding risks for coastal communities (Gomez et al., 2020).

An aerial image posted on Google Earth shows the drastic retreat of the coastline at Cap Cameroon. The image shows the FM radio aerial, which was built in 1972 in the middle of the area, but in 2018 is more than 518 meters deep in the ocean (Figure 10).

Central Africa experiences severe deforestation, losing about 9 million hectares annually due to illegal logging and agriculture (Nasi et al., 2021, Eba'a et al., 2021), making it one of the highest deforestation regions globally (FAO, 2018). Climate change, with rising sea levels and more frequent storms, complicates coastal management (Dada et al., 2024). An integrated approach that considers environmental and social dynamics is vital for community resilience. In Gabon, Congo-Brazzaville, and the DRC, coastal erosion arises from similar factors. Moukala et al. (2021) note that rising sea levels worsen degradation, while Kouadio (2022) highlights the impact of resource exploitation on marine ecosystems. Ndinga and Mavoungou (2023) emphasize how poorly planned infrastructure disrupts sediment dynamics, worsening erosion. Sustainable coastal management is essential to mitigate these impacts (Moutou et al., 2022).

Coastal erosion is also widespread along the Atlantic African coast (CSE/UICN & FFEM, 2021; Guerrera et al., 2021; World Bank, 2021). Countries face significant erosion rates, including Togo with 8–12 m/year (UEMOA, 2007), Benin with 12–30 m/year impacting 10.9 million people (Sego, 2019; Ozer et al., 2017; World Bank, 2021), and Senegal with 718 km coastline affected, including the Saint-Louis area retreating 6 km since 2003 (Kane, 2023). The Niger Delta has lost 5.16–5.38 km^2 of land between 1990 and 2021 due to deforestation-linked erosion (Desmond et al., 2022). These countries face high vulnerability levels, with cities like Lagos, Accra, and Dakar most at risk (Figure 10). With an average coastal erosion rate of 10.2 m/year, the Wouri Estuary experiences similar retreats, which deeply impact the lives of the local population.

5.2. Environmental degradation and population vulnerability in Africa

Mangrove degradation in Central Africa is a growing problem exacerbated by rapid urbanization and anthropogenic pressures. In Cameroon, for example, the coastal population is gradually increasing, accentuating the pressure on mangrove ecosystems through abusive logging. This compromises their ability to regenerate and protect the coast against erosion and flooding. According to These ecosystems are crucial role in stabilizing coasts and preserving biodiversity (G. Ajonina et al., 2014).

The Wouri estuary faces severe environmental challenges due to rapid mangrove degradation (7.5% annually), threatening coastal stabilization (IUNC, 2015). Cameroon loses over 300 ha of mangroves annually (FAO, 2006), despite protected areas, due to financial constraints and corruption.

Research indicates that mangrove deforestation in Gabon has resulted in a significant loss of surface area, with around 685 square kilometers lost between 1980 and 2005 (Mfou'ou Awana, 2020; Mouketou-Tarazewicz et al., 2021; Ndonghan Iyangui et al., 2020). In contrast, Benin's RAMSAR site effectively protects mangroves (Padonou et al., 2021). Population growth and urban/agricultural expansion drive degradation, similar to Ghana (Winston et al., 2017). Environmental degradation increases exposure to hazards like coastal erosion and storms (Othman, 1994), highlighting the need for effective conservation and management.

The populations living in these mangroves are therefore particularly vulnerable to the impacts of climate change and the degradation of their environment (Naidoo, 2023, Mfou'ou Awana, 2020)). These communities rely heavily on the resources provided by mangroves, such as fish and other marine products, for their livelihoods. According to G. Ajonina et al. (2014), deforestation and degradation of mangroves, exacerbated by urbanization and industrial activities, compromise not only biodiversity but also the livelihoods of these populations.

Research by Shisanya and Mafongoya (2017) in South Africa, Adaawen (2021) in West Africa, and Pyhälä et al. (2016) in the African continent in general, highlights the importance of local perceptions and individual actions in understanding climate change, resource use, and global changes in Africa. Local communities are aware of environmental changes in Central Africa, with Manoka scoring higher (3.37/5) than Cape Cameroon (2.9/5) in socio-ecological exchange. Despite facing severe environmental pressures, Cape Cameroon residents have developed a strong understanding of their environment (3.64/5), aligning with the theory of cognitive feeling. The community is highly aware of degradation and has formed a vigilance committee against illegal logging. Manoka has developed agriculture, with fisherwomen cultivating diverse crops.

5.3. Vulnerability of the population due to coastal erosion in African country

This study analyzes the vulnerability of marginalized populations to coastal erosion and environmental degradation in Central Africa. The Wouri estuary experiences an alarming erosion rate of 10.2 m/year, affecting 41.7% of the coastline and impacting over 80% of residents dependent on fishing. This leads to housing losses and declining living conditions. Mangrove degradation, at a rate of 7.5% per year, worsens the situation as these ecosystems are vital for coastal protection. Their destruction is linked to agro-industrial expansion and urbanization, similar to challenges faced in Ghana and Senegal. The study emphasizes the urgent need for adaptation and sustainable management strategies, inspired by successful initiatives like the WACA project (Gomez et al., 2020Nasi et al., 2021; Moutou et al., 2022). Improving adaptive capacity is essential to mitigate vulnerabilities, with exposure often being the critical trigger in the Wouri estuary context.

In the Wouri estuary, coastal dynamics show 41.7% erosion, 39.3% stability, and 19% accretion (1975–2020). While previous studies linked coastal retreat to mangrove loss (Ellison & Zouh, 2012; Fossi Fotsi et al., 2019), our results reveal a more complex situation. Coastal erosion hotspot (10 m/yr) occurs around Cape Cameroon, influenced by factors beyond mangrove loss. Despite widespread impact, coastal erosion is ranked as the most important hazard by only 8% of the population (Tataw et al., 2021). This suggests high resilience, with adaptive strategies like stilt houses.

Recent studies conducted in West Africa, including those by Cormier-Salem et al. (2017), highlight the severe erosion experienced by these coasts. They show the importance of mangrove ecosystems in protecting coasts and the need to adopt sustainable management strategies to mitigate the effects of erosion and strengthen the resilience of coastal communities (Badiane, 2016; Ndour et al., 2018).

In addition, the work of the Laboratoire Mixte International 'Patrimoines et Territoires de l'Eau' highlights the complex issues linked to the degradation of biodiversity and the fight against poverty in these vulnerable regions. Coastal communities, which rely heavily on maritime resources for their livelihoods, are particularly affected by erosion, threatening their homes and livelihoods. According to an IOC-UNESCO report, countries such as Cameroon and Gabon face significant challenges related to coastal erosion, with potential impacts on the local economy and food security (IOC-UNESCO, 2020)).

Inland populations face significant climatic hazards, including wind storms, intense rainfall, temperature rises, and sea-level rise (Fongnzossie et al., 2022). Extreme weather events are intensifying globally, particularly in Africa (Goodess, 2013; UNDP, 2000). Coastal regions experience sea-level rise, erosion, and flooding (Torresan et al., 2008). In Manoka, Fongnzossie et al. linked climate change to community vulnerability. Our survey reveals feelings of helplessness despite some resilience, emphasizing the need for education. Vulnerability hotspots include Burkina Faso, Niger, Nigeria, and Chad, with poverty exacerbating risks (Thornton et al., 2008). The World Bank Group (2024) links vulnerability to income levels.

The perception of environmental change: a key to understanding the vulnerability of African populations?

6. Conclusion

This study investigates the vulnerability of marginalized populations to coastal erosion and environmental degradation in Central Africa, highlighting concerning findings. The Wouri estuary faces an average erosion rate of 10.2 m/year, impacting 41.7% of its coastline and significantly affecting over 80% of residents reliant on fishing. This results in housing losses and deteriorating living conditions. Mangrove degradation occurs at a rate of 7.5% annually, exacerbating the situation, as these ecosystems are crucial for coastal protection and essential services. Their decline is linked to the growth of agro-industrial plantations and urbanization, similar to challenges in Ghana and Senegal. The study emphasizes the relationship between urbanization, biodiversity loss, and increased natural hazards, such as flooding. It calls for urgent adaptation and sustainable management strategies, inspired by successful initiatives like the WACA project in West Africa, which aim to enhance community resilience. Ultimately, the vulnerability of coastal populations arises from their exposure to environmental risks, compounded by socio-economic factors. Improving adaptive capacity is vital to mitigate these vulnerabilities, with exposure often serving as the key trigger in the Wouri estuary context. Integrated approaches to managing coastal resources are essential for addressing these challenges.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Authors' contributions

Philippes Mbevo Fendoung led fieldwork, data analysis, and writing. Aurélia Hubert-Ferrari developed methodology and oversaw the writing process. Mesmin Tchindjang and Serge Schmitz contributed to conceptualization, fieldwork, and manuscript preparation. All authors contributed to manuscript review and approval.

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