Prevalence of the vulnerability to coastal erosion: Case study of Saint-Louis city

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PREVALENCE OF THE VULNERABILITY TO COASTAL EROSION: CASE STUDY OF SAINT-LOUIS CITY

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Abstract

The coastal areas of Senegal are increasingly affected by climate change and Anthropogenic activities. Accelerated Sea level rise is actually resulting in serious processes of coastal erosion with huge environmental and socioeconomic damages. The city of Saint-Louis is particularly sensitive to coastline retreat as the phenomenon has become recurring with significant impacts along the "Langue de Babarie" sand spit. That particular area is undergoing huge losses of human settlements even if solutions have implemented and affected populations temporally relocated inland. People and economic activities are therefore threatened by coastal erosion. The ongoing urbanization has deeply disturbed the natural sedimentary transit of the coastal area as such practices like sand beach extraction induces serious sedimentary imbalance. Human and environmental security in this coastal part of the country becomes an emergency, given the high vulnerability to marine submersion. Facing coastal erosion should be therefore based on sustainability rather than technical solutions. This paper is aimed at analyzing population' behavior to the various coastal protection measures put in place by local authorities.

Keywords: coast, coastal erosion, risk, vulnerability, security

Introduction

Coastal dynamics result from all sedimentary processes in the environment. Coastal erosion occurs when there is any imbalance between sediment loss and sediment supply. The environment then seeks to regain the sedimentary balance leading to deep changes in the configuration of the coastline (Baillargeon and Crousset, 2006). Regional climate changes, storms, relative sea level fluctuations natural sediment supply variation as well as human activities are the main drivers of coastal erosion. The latter, a natural process that allows the transit of sediment, has become very active and results in shoreline retreat. The land areas adjacent to the world's shorelines are associated with large and growing concentrations of human population, settlements and socioeconomic activities, including many of the world's largest cities (Small and Nicholls, 2003). Similarly, the coastlines have long been experiencing a real spatial and demographic expansion. Generally speaking, more than 50% of coastal countries have more than 80% of their total population living within 100 km of the coast. Twenty-one of the world's thirty-three megacities are also located along coastlines (Martinez et al. 2007). In addition of being environmentally destructive, coastline retreat is socioeconomically traumatic for unprotected populations still exposed to marine submersion. Communities and social group are differently affected by natural hazards. Some population groups possess higher adaptive capacities. They are endowed with the attributes and resources that can be used to accommodate negative impacts or exploit the beneficial opportunities arising from a hazardous event (Felsenstein and Lichter, 2014). The city of St. Louis is vulnerable to multiple risks such as coastal erosion, marine submersion and flooding.

Shortlisted as a UNESCO World Heritage Site in 2000 (1) , the city of Saint-Louis is located along the northwest coast of the Senegal at the mouth of the Senegal River. Its population was estimated at 232,000 inhabitants in 2017. The "Langue de Barbarie", a thin sandy peninsula of about 100 to 400 meters width constitutes the edge of the Atlantic and naturally separates the ocean and the Senegal River. That fragile and protective sand spit of 35 to 40 Kilometers length of sand dunes is actually experiencing an accelerated urban ecrochament leading the installation of conservative fishing communities in a highrisk area.

Methods

The city of Saint-Louis appears to be a space where various hazards can cause significant damage. Its occupation makes these areas vulnerable for the local populations living there. The major objective is to analyze the behavior of the "Langue de Barbarie" dwellers toward coastal protection facilities implemented by authorities. We favored the participatory method to obtain qualitative information and a global and diversified approach to the issue. We interviewed about fifty persons aged between 30 and 50 years old who live in the "Langue de Barbarie". Overall, the questions were asked to fishermen who represent the majority of the population and whose activities and behaviors are impacting the coastal protection facilities.

1. Study area

The city of Saint-Louis is located within the delta of the Senegal river. The river enters the ocean through an inlet and the inlet cuts off a sandspit in the North called "Langue de Barbarie". "The Langue de Barbarie" spit is a 100-400 m-wide feature that has fluctuated in length between 10 and 30 km over the last century. The spit is capped by a 5-10 m high dune. The river-mouth depths range from 2.5 m in the rainy season when sand deposition results from high river discharge to 3.5 m in the dry season, when sediment flushing is assured essentially by tidal currents (Bersgma et al. 2020). The "Langue de Barbarie" is a sandy coastline oriented north-south, consisting of three districts (Goxu Mbax, Ndar Toute and Guet Ndar) (fig. 1). It is located in the west of the island and separates the river from the ocean. This spit of fine white sand is the result of a long alternating process of beach nourishment and de-migration due to longshore drift. It is the southern end of the "Langue de Barbarie" that determines the position of the mouth of the river, which has frequently migrated southward, dragging along the "Langue de Barbarie" spit, which has neither widened nor risen since its origin (Gac et al 1982).

Fig. 1: The "Langue de Barbarie" Sand spit and Coastal Communities/Districts

The "Langue de Barbarie" is a product of strong wave action and high longshore sediment transport during the mid-17th century. A historical analysis of the spit' mobility associated locations of mouth controlled the morphosedimentary development of the seaward fringe of the Senegal River delta (Sadio

[1] https://whc.unesco.org/fr/list/956/

et al, 2016). Coastal erosion is a natural process by which coastlines adjust to varying sea levels, energy levels, sediment supply and existing topography (Cooper and McKenna, 2007). These natural factors are more destructive in marine front areas characterized by high vulnerability.

2.Hazards in a vulnerable area

The vulnerability concept is often used more broadly to describe the degree of exposure (Rangel-Buitrago et al. 2020). Africa is particularly exposed to sea-level rise and coastal erosion (Taveneau et al. 2021). In many parts of the world, human activities in the coastal areas have increased natural subsidence causing a faster sea-level rise than the projected acceleration due to global warming. Therefore, coastal states must seek solutions for their current problems which accommodate the potential impacts of future sea-level rise (Chemane at al. 1997). The Senegalese coastline is very sensitive to sea related hazards with wave heights of over 4 m par example in Saint-Louis (fig. 2). This situation is particularly devastating with significant damage recorded throughout the coastline. Recurrent surges may result in serious erosion process capable of opening a new communication with the sea in the most fragile areas. Along the “Petite Cote”, the Sangomar spit, which is an important sandy area extending for about twenty kilometers southward from Palmarin Diakhanor, plays a key protective role for the landscapes of the Saloum estuary. The lower part of the estuary is subject to significant pressure due to aggressive surges and the break-up of February 1987 on the Sangomar spit. The spit broke during a storm inducing strong northwest swells (Dieye et al. 2013). Senegal’s low-lying coasts show signs of increased vulnerability to coastal flooding (Cissé et al. 2023). Marine submersion is a problem of varying intensity along Senegal’s coasts, with the cities of Saint-Louis and Dakar being the most exposed (Quiroga et al. 2022).

The Senegal River estuary is increasingly affected by coastal erosion. The populations of the "Langue de Barbarie" are exposed to the effects of swell movements. Saint-Louis has also been vulnerable to climate change related

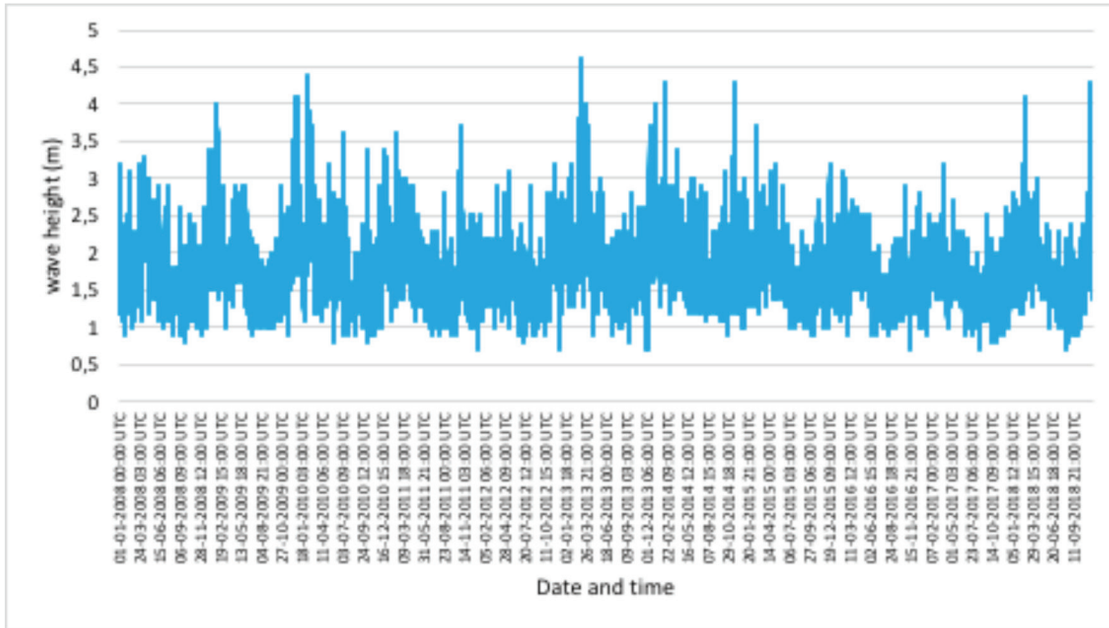

Fig. 2: Wave height in Saint-Louis (2008-2018) (Data extracted from WAVEWATCH 3 Model (WW III) NOAA)

hazards, including coastal erosion, sea level rise and flooding.

The coastline is actually experiencing serious coastal erosion phenomena particularly significant in the fishing communities of Guet Ndar, Ndar Toute and Goxumbacc. This phenomenon stems fromfrom the combination of both natural andanthropic factors. The interference of the swell and the waves causes an agitation of the sea. This action is maximized when a storm occurs at the same time as high tide. Major shoreline changes occur abruptly when these conditions are met. The action of these nearshore agents is to eat away at the shoreline and release sediment. Land use and sand removal contribute to this intensification. The sand carried by waves and currents is naturally replaced by sediments from the erosion of marine sandbanks. The urbanization of coastal areas leads to a disruption of the natural sedimentary transit. Similarly, sand extraction induces an imbalance along beaches when the sedimentary contributions become insufficient. Coastal cities have been subjected to extreme weather events since the onset of urbanization. Climatic change, in particular sea level rise, coupled with rapid urban development are amplifying the challenge of managing risks to coastal cities (Dawson et al, 2018).

Several authors (Dwarakish et al. 2009; Addo 2013; El-Hattab 2018; Tragaki et al 2018; Sekovski et al. 2020) used Coastal Vulnerability Index (CVI) originally proposed by Gornitz, White and Cushnam (1990) and Gornitz (1991) as an index-based method to assess coastal vulnerability to climate change, particularly to sea level rise (SLR) (Pantusa et al. 2022). Koulibaly (2021) used the Coastal Vulnerability Index (CVI) to estimate vulnerability of the Saint-Louis and found that it varied from 7.90 to 22.82 with a mean of 15.45 and a standard deviation of 4.22. The six ranked variables (geomorphology, coastal slopes, relative sea level rise, shoreline change, mean tide range and mean wave height) were assigned to the coastline in a GIS database and CVI was calculated using the formula. Categorization from Low-Moderate-High-Very High vulnerability was done using 4 equal intervals and each CVI value falls in its relevant interval. The same study also revealed that 70% of the shoreline of Saint-Louis was extremely vulnerable. The two largest fishing areas of Guet-Ndar and Goxxumbacc, were the principal areas of high vulnerability to coastline retreat (fig. 3). The coastline around Goxumbacc was mainly experiencing accretion rate of about 4.27 m/year while the section stretching from Ndar Toute to Guet Ndar was still affected by erosion rates ranging from -0.15 to -3.51 m/year. The coastline of Saint-Louis experienced more accreted than eroded areas from 2008 to 2018. The Eroded surfaces mainly located around Guet Ndar, Ndar Toute and around the new mouth of the Senegal River were estimated at 2.15 km², an annual rate of 0.215 km²/year. Accreted areas were estimated at 3.543 km² (0.354 km²/year) mostly noticed in Goxumbacc. Within that decade, the coastline recorded an excessive sedimentary balance of 1.394 km2.

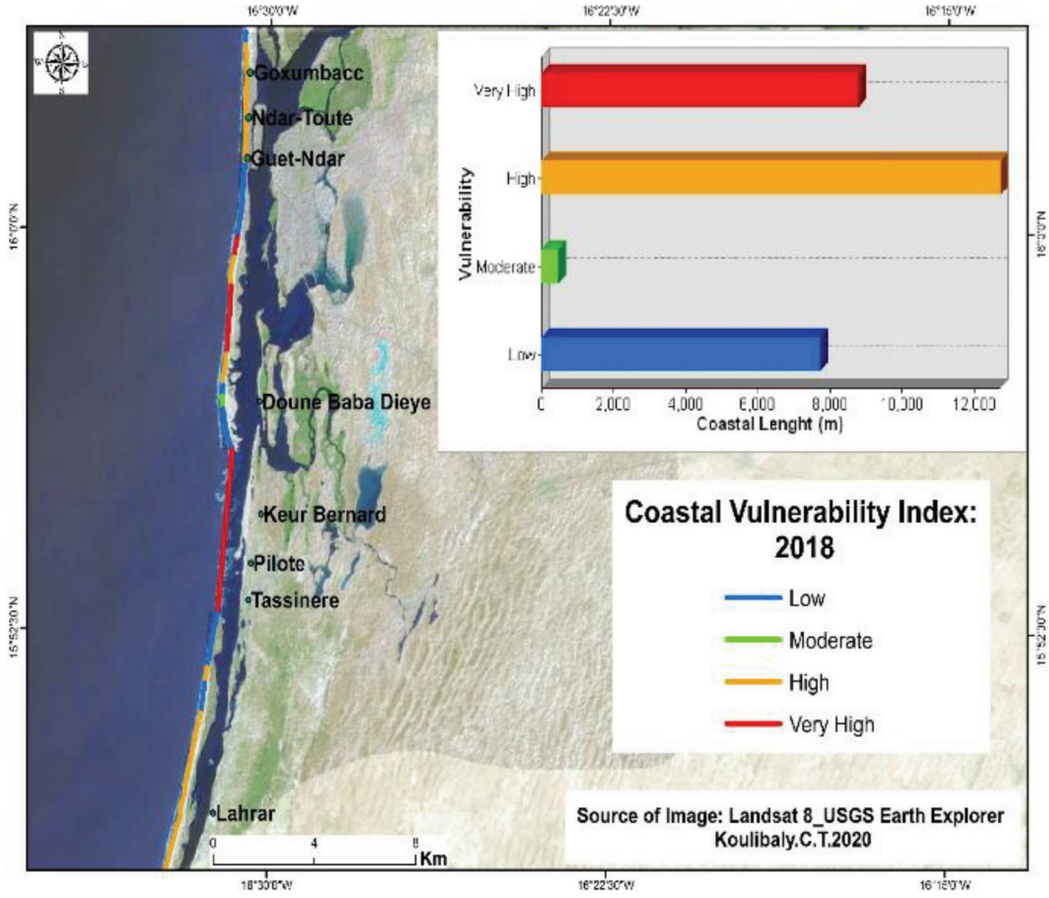

Fig 3 : Vulnerability to Coastline retreat (Koulibaly, 2021)

Sambou et al. (2019) calculate the average erosion rate by linear regression is 0.35 m/year between 2000 and 2018. In the sector from Guet-Ndar to Goxu-Mbathie, the rate of change is 0.69 m/year. According to Bergsma et al. (2020), in addition to erosion trends, the erosion rate has increased over the past two decades around the Saint-Louis fishmarket. Seawalls and harbours are hard vertical structures in addition to buildings close to the shore, or even on the beach highly limit the natural variability. Field observations helped to realize that ongoing socioeconomic activities such as fishing are seriously affecting coastal protection facilities which are partly silted up to serve as pathway for people and fishing boats along the "Langue de Barbarie" sand spit. This tends to prove that anthropic activities are increasingly responsible for the evolution of coastal ecosystems.

3. Resilience strategies for coastal communities

The vulnerability of coastal countries is exacerbated by their significant population growth and their climate backgrounds (drought periods, monsoon). Thus, reducing the vulnerability of the "Langue de Barbarie" is a major challenge of local governance and a high-profile act in the resilience strategies of coastal communities to hazards. The "Langue de Barbarie" barrier beach is an unstable area subjected to both accretion and erosion phenomena. The accretions of littoral sand can be explained by marine dynamics suppying sandy sediments coming from the mouth. Coastline change analysis from 1978 to 2018 revealed that erosion was active in 65.04% of the coastline while 10.32% recorded accretion (Koulibaly, 2021).

In 2018, the Senegalese government, and its technical and financial partners, has undertaken measures to strengthen the protection of the "Langue de Barbarie" population. These measures have resulted in the initiation of two major projects including the Coastal Protection Project in Saint-Louis and the Emergency Recovery and Resilience Project in Saint-Louis. Measures to protect the "Langue de Barbarie" in 2018 mostly included A gabion wall of about:

- 1.5 kilometers length
- 1.5 meters and 3 meters height

A frontal protection dyke of over 2150 m lenght has been built along the urbanized area of the "Langue de Barbarie". The objective was to protect the populations and social amenities against coastal erosion.

4. Analysis of population's behavior

Cultural background could also have an influence on people's perceptions and behaviors in response to hazards. For example, the different cultural backgrounds of two people could influence the decision of one to raise their house on poles and of the other to raise their floor by mud-piling (Munji et al. 2013). Communities and social group are differently affected by natural hazards. Some population groups possess higher adaptive capacities. They are endowed with the attributes and resources that can be used to accommodate negative impacts or exploit the beneficial opportunities arising from a hazardous event (Felsenstein and Lichter, 2014). The "Langue de Barbarie" is inhabited mainly by modest fishing communities whose houses, which had been there for several generations, were washed away by heavy storms caused by the northwest swell. In November 2018, for example, the arrival of storm surges with swells over 4 m high from the northwest were described by the local press as "terrifying wave impacts" (Kane, 2019). The World Bank (2018) report also states that in August 2017 and February 2018, significant storm surges caused extensive damage, with 259 families (approximately 2600 people) relocated in very precarious conditions east of Saint-Louis City. The rise in sea level has destroyed and washed out several houses and schools and even threatened the main town of Saint-Louis.

Vulnerability is explained by the lack of local people' adaptive capacity. The Implemented coastal protective measures are poorly managed by the populations: silting up and subsidence of gabion basins and frontal dikes used dumpsite (fig.3a). There is lack of culture of risk from local populations. In some areas, protective facilities are partly silted up to serve as pathway for people (fig. 3b) and fishing boats. Thus, vulnerability can be both inherent to the system and induced by the relationships between the system and its environment.

Fig. 3: Silting of protective dykes (2022)

Survey have shown that populations over 40 years old declare that they have been expose to coastal erosion since the 1970's. Some of them have lost their houses while others are haunted by the fear of waking up homeless because of the waves taking over their houses. A form of fatalism remains in the coastal communities that are directly affected by coastal erosion. Some of the people interviewed mentioned their powerlessness in the face of the ocean's force.

Although the populations feel threatened by coastal erosion, they are not ready to leave the "Langue de Barbarie" because it is the workplace. They have experienced such hazard in the past and some of them have lost their properties. At the social level damages have been noticed especially as regards schools.

The government and its partners have implemented projects to relocate over fifteen thousand people. However, many of local dwellers refused to be moved from their natural habitat to inland. The populations confirmed the effectiveness of the protection measures set up by the authorities but are not aware of the impacts of their behavior on these facilities. Moreover, the determination of the risks and stakes on this coastal strip should modify the behavior of the populations. It is also important to question the sustainability of these coastal protection facilities with regard to accelerated sea level rise and climate change. is rising faster than expected.

Conclusion

In a context of climate change, there is a recurrence of coastal erosion but this area is also characterized by a fragile sandy spit. There is also lack of perception of risk from local populations. As conservative fishing communities, these populations hardly accept to leave their ancestral place of life and work. There is a threat of creating a shift between the population and their social as well as professional stability. This situation should be included within the context of climate justice. In this perspective, anthropogenic factors and climate change will constitute exacerbating factors of marine submersion.

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