Assessing Mozambique's exposure to coastal climate hazards and erosion

Pedro Cabral[a,*], Gabriela Augusto[a], Adeoluwa Akande[a], Anjos Costa[a,b], Nelson Amade[a,b], Sérgio Niquisse[a,b], Ali Atumane[a,b], António Cuna[a,b], Kiana Kazemi[a], Ramires Mlucasse[a,b], Rubini Santha[a]

[a] NOVA IMS, Universidade Nova de Lisboa, 1070-312, Portugal
[b] Universidade Católica de Moçambique, Beira, Moçambique

ARTICLE INFO

ABSTRACT

An increasing number of people in the world are living in coastal areas characterized by high geophysical and biophysical sensitivity. Thus, it is necessary to provide coastal planners with tools helping them to design efficient management plans to mitigate the negative effects caused by a growing number of coastal climate hazards that threaten life and property. We calculate an Exposure Index (EI) for the coastline of Mozambique and assess the importance of the natural habitats in reducing exposure to coastal climate hazards. We estimate, for year 2015, an increase of 276% in the number of people affected by a high, or very high, level of exposure when compared to a "Without habitats" scenario, i.e. excluding the protective effects of sand dunes, mangroves, and corals. The results of the EI are supported by the Desinventar Database, which has historic data concerning loss and damage caused by events of geological or weather related origin. These results also indicate where the most exposed areas are thereby providing useful information to design effective coastal plans that increase resilience to climate hazards and erosion in Mozambique.

1. Introduction

The severity of the impacts of extreme and non-extreme weather and climate events depends strongly on the level of vulnerability and exposure to these events [1]. It is widely accepted that coasts will be exposed to increasing climate hazards in the coming decades due to climate change and sea-level rise [2]. Exposure is defined as "the situation of people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses" [3] and vulnerability refers to "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" [2]. Exposure is also referred to as biophysical vulnerability, site, and situation of the place, whereas vulnerability is referred to as social vulnerability comprising the built environment and the social fabric [4,5].

Coastal regions are particularly exposed, although with different levels of vulnerability, to the adverse effects of climate change and sea-level rise, leading to increased risks that include loss and damage by climate hazards and coastal erosion, which may be exacerbated by increasing human-induced pressures [6]. However, coastal areas are attracting an increasing number of people because they often provide more subsistence resources than those found inland, more access points

to marine trade and transport, more recreational, and cultural opportunities and, for some, a special sense of place at the land/sea interface [7]. This population growth, and the associated high urbanization rates, are driven by fast economic development and migration toward the coast [8,9]. Consequently, the degree of exposure coastal populations is being boosted by the pressures added to coastal systems that need to accommodate more and more people and associated infrastructures [10,11], and by the expected increase in coastal flooding and sea level rise [12]. The exposure of coastal areas depends greatly on their geomorphologic characteristics, and a significant reduction in the exposure of coastal areas to climate hazards and erosion can be achieved through the conservation of natural habitats that provide protection to the coast (e.g. dunes, mangroves, corals, seagrasses, etc.), or by building coastal protection infrastructures [13–16]. The former is generally an option for most countries, but the latter is only viable for countries that can afford to pay for expensive engineering infrastructures [17].

The need exists to study coastal exposure and a considerable number of studies have been carried out for many regions in the world using different methodologies [10,13,18–23]. However, with some exceptions [24,25], these studies are scarce for Africa. Historic data availability for African countries, and particularly on sea-level rise, is
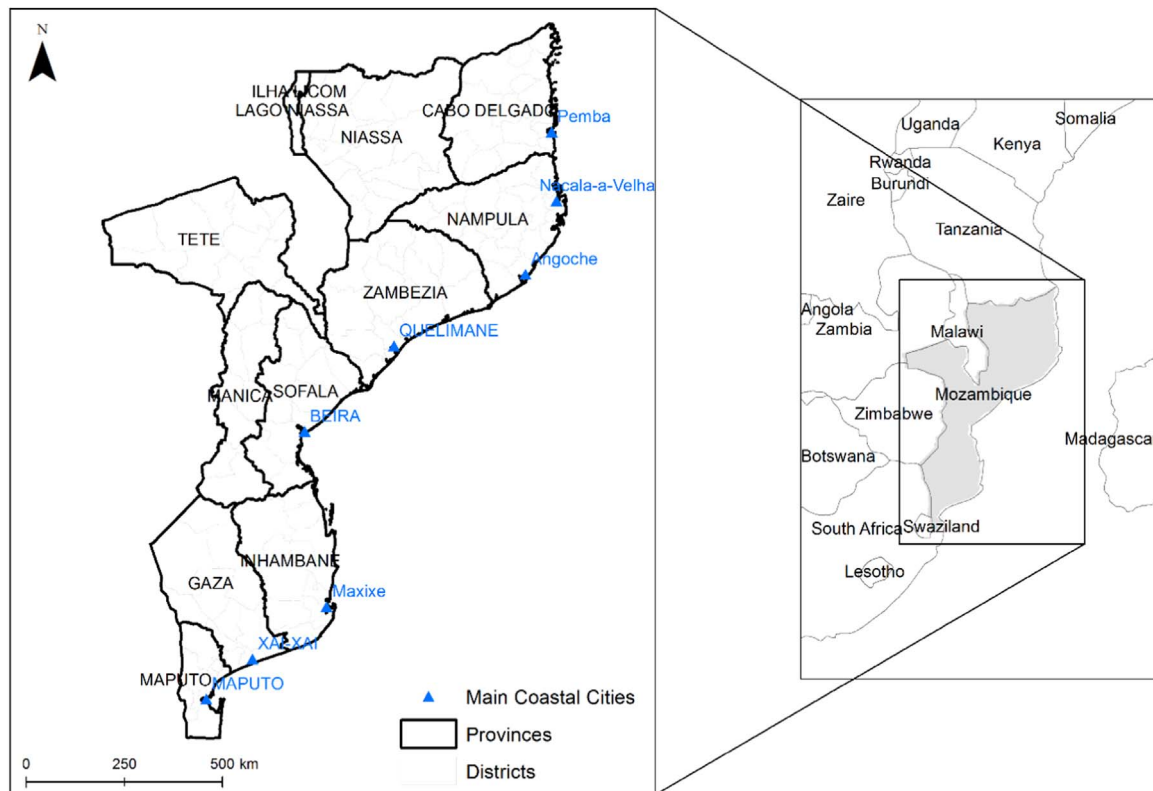
Fig. 1. Study area.

fairly limited when compared to other regions in the World [26]. In Mozambique, a country that has been identified as being particularly exposed to increased flooding due to the occurrence of tropical storms [1,27,28], with the exception of a study for the city of Beira [28], there is no study reported to date about exposure to coastal climate hazards and erosion. Besides having one of the longest African coastlines (approximately 2700 km) this country also has approximately 60% of its population located in coastal districts [29–31].

In this article we calculate the exposure index of the Mozambique coast to climate hazards and erosion using a 1 km² spatial resolution. To assess the model pertinence, the results of the exposure index (EI) are compared with the Desinventar Database [32], which has historical data concerning loss and damage caused by events of geological or weather related origin. We also assess the importance of the habitats in reducing exposure to coastal climate hazards and erosion.

2. The study area

Mozambique is located in southeast Africa and comprises a land surface of about 800,000 km². Maputo is the capital and the country's largest city (Fig. 1). The country had an estimated population of 25 million inhabitants in 2014 [33]. About 70% of Mozambicans live in rural areas, and 40% of them are located in the districts of Nampula and Zambézia [33]. About 45% of the population is under 14 years old, and the elderly represent about 3.5% of the total population [33]. Typically Mozambicans live in large families, 53.9% of the families have more than 5 members, and the presence of collateral related family, or unrelated elements in the household is relatively common (15%) [34]. The purchasing power in Mozambique has been rising sharply, but on average each Mozambican spends less than 21 USD per month, or about 14 USD per month if living in a rural area [34]. Most lodgings are built of adobe; only 18% of the houses are made of bricks, and 30% of the families live in houses made of precarious building materials [34]. Safe water supply reaches roughly half of the households, and the electric utility network is poor or nonexistent in rural households. Safe

sanitation covers less than 1% of rural households. Nearly 45% of the Mozambican population cannot write or read, and this percentage is higher among women (58%) [34].

Mozambique is divided into 11 provinces and shares borders with Tanzania, Malawi, Zambia, Zimbabwe, South Africa, and Swaziland. After a devastating civil war that ended in 1992 [35], the first democratic elections took place in 1994, and since then the country has enjoyed political stability and rapid economic growth (7.4% of annual GDP growth in 2014) [36]. A Gross Domestic Product (GDP) of US$16.961 billion and a Gross National Income (GNI) per capita of US$600 in 2014 [36] make Mozambique one of the poorest countries in the world. This country ranked 180th out of 188 countries in the most recent Human Development Index (HDI) [37].

There are 104 identified river basins flowing into 11 major rivers, with the Zambezi and Limpopo being the two largest, that drain the water from the Central African high plateau into the Indian Ocean [38,39]. The majority of the rivers have a torrential, wet season regime with high waters during 3–4 months, and low, dry season flows (sometimes totally dry) for the remainder of the year. Up to 52% of the country is within international river basins [39]. The continental shelf is wider in the center (approximately 145 km, near Sofala), decreasing in both north and south [40,41].

The Mozambican coast is divided into three main areas: the sandy coastline in the south, the estuarine coast in the center, and the coralline coast, with coral limestone in the north [40,42]. The sandy coastline starts at the South African border and extends to the Save Delta. It is a lowland coast dominated by sand dunes, lakes, lagoons, and bays receiving river estuaries, namely the Maputo bay, which accepts the estuaries of four rivers [41,42]. This lowland coast is bordered by an extensive dune system [41] dominated by wetlands of the deltas of large rivers in the estuarine coastline. The estuarine coastline starts at the mouth of the Save (130 km south of Beira), and extends to Angoche, encompassing the Zambezi river delta. The coralline coastline covers over 700 km from Angoche until the Tanzanian border. This is a narrow coastline with the bordering plateau sloping