Informing Adaptation to Coastal Hazards: Strengthening Communication of Sea Level Rise and Cyclone Risk in Maputo Planning Policy Spaces

This project is part of the Oppenheimer Programme in African Landscape Systems (OPALS) at the University of Exeter.

"I certify that this dissertation is entirely my own work, and no part of it has been submitted for a degree or other qualification in this or another institution. I also certify that I have not collected data nor shared data with another candidate at The University of Exeter or elsewhere without specific authorisation."

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This work is not just a research project, but a personal journey dedicated to the memory of my father Juliao Francisco Cossa. His memory and our shared journey have been a source of inspiration and strength throughout this work.

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Abbreviations

INAM – National Institute of Meteorology

INGD/INGC - Mozambique National Institute of Disaster Management

INE – National Institute of Statistics

InOM - Institute of Oceanography of Mozambique

IPCC - Intergovernmental Panel on Climate Change

MTA - Ministry of Land and Environment

SLR – Sea Level Rise

TC – Tropical cyclone

UEM - Eduardo Mondlane University

UN – United Nations

UNDRR – United Nations Office for Disaster Risk Reduction

Abstract

Coastal settlements such as Maputo in Mozambique faces increasing vulnerability to coastal hazards such as rising sea levels and cyclones. Significant gaps in integrating scientific information on these changing hazards into urban planning policies hinder effective adaptation strategies. This study explores the existing gaps and challenges in communicating these hazards through a survey of 31 respondents based in Maputo who are involved in climate science and urban planning. Results revealed that technical complexity (19.4%), language barriers, and institutional constraints are perceived as key communication challenges. Only 29% of respondents believe that climate disaster science is fully integrated into urban planning, with insufficient funding, unreliable data, and complex scientific models cited as integration challenges. This study underscores the need for tools that effectively communicate uncertainties and appropriate confidence levels in climate risk data, alongside the necessity for regular, accurate data and strengthened institutional coordination, to better integrate climate risk information into urban planning practices in Maputo.

Keywords: Coastal hazards; Sea Level Rise; Cyclone; Science Communication; Adaptation; Maputo; Urban planning policy.

1. Introduction

Mozambique experiences significant repercussions from climate change and natural calamities (Mucova et al., 2021). With a coastline of ca. 2700 km, the country is at high risk of erosion and coastal climate hazards. Furthermore over 60% of the population resides in low-lying coastal areas that are prone to sea level rise and climate fluctuations (Zehra et al., 2019). Mozambique is ranked 39th in vulnerability and 24th in preparedness to address climate change, reflecting inadequate preparation and significant vulnerability (Arnall et al., 2013).

The World Bank and Mozambique National Institute of Disaster Management (INGD) designated Maputo, Mozambique's capital, as a highly vulnerable area to climate change in 2010 (Zehra et al., 2019). As a low-lying coastal city located along the Indian Ocean, it is at risk from high temperatures, internal flooding, pluvial erosion caused by rainwater runoff, and coastal erosion due to sea wave dynamics (Barros et al., 2014).

The city is particularly vulnerable to rising sea levels and more frequent and intense storms and cyclones (UN-Habitat, 2010). Research suggests that the sea level in the coastal sections of the Municipality of Maputo could increase by 10 cm by 2030 (low scenario) and by 20 cm to 100 cm by 2060 (medium scenario) (Zehra et al., 2019). The anticipated rise in sea level could have detrimental effects on low-lying coastal regions, leading to flooding, diminished agricultural practices, and infrastructure destruction (Amir et al., 2024). Additionally, the population at risk of flooding due to rising sea levels may continue to increase until the end of the century (Neumann et al., 2015). Furthermore, the rise in sea level may also lead to a more pronounced degradation of mangroves and coral reefs and bring additional consequences for fisheries and tourism (Mather and Stretch, 2012).

These hazards have the potential to exacerbate existing socio-economic inequalities, threaten critical infrastructure, and disrupt livelihoods, particularly in informal settlements and peri-urban areas located in low-lying coastal zones (Amir et al., 2024). Enhancing the dissemination of information regarding sea level rise and cyclone risks enables stakeholders to effectively forecast, mitigate, and manage the impacts of coastal threats. Such improved communication facilitates urban resilience by bolstering the city's capacities for resistance and recovery from these events, aligning with its objectives for sustainable urban development (Uzochukwu et al., 2016).

This dissertation is part of the Oppenheimer Programme in African Landscape Systems (OPALS), which is a collaboration between the University of Exeter and the Oppenheimer

Generations Research and Conservation. The goal of this project is to enhance resilience to coastal hazards, such as Sea Level Rise and storm surges, in southern Africa. The specific objective is to assist planners in integrating information and decision-making tools related to coastal hazards into their decision-making processes and Maputo has been selected as the focal city for this research.

1.1. Aim

Assess the challenges in current science communication strategies to better connect predictions of sea level rise and cyclones with planning policies in Maputo.

1.2. Research questions

1. What are the existing mechanisms for communicating sea level rise and cyclone risk information within Maputo's urban planning policies?
2. What are the main challenges for communicating sea level rise and cyclone risk information within Maputo's urban planning policies?
3. What are the critical elements to ensure effective communication and translation of sea level rise and cyclone risk information into Maputo urban planning policies?

1.2. Problem

Currently, climate change assessment and effect studies have primarily concentrated on a national scale, resulting in insufficient adaptation strategies and measures at the municipal level (Barros et al., 2014). Additionally, the availability of coastal information is poor, although data on cyclone events and SLR projections are available, a disconnect remains at the intersection between science and decision-making, i.e., between the information and knowledge produced by scientists and the information and knowledge applied by urban planners (Mather and Stretch, 2012).

Effective communication of hazard data is crucial for informing adaptation measures in urban planning policies and building resilience to coastal hazards in Maputo (Mucova et al., 2021). However, existing communication strategies may face challenges in effectively translating scientific information into actionable policy decisions. Limited access to reliable data, language barriers, and a lack of awareness among policymakers and stakeholders about the severity and urgency of the coastal hazards further hinder effective communication efforts (Uzochukwu et al., 2016). Maputo urban planners are not doing much to integrate climate risk or adaptation measures into the city due to a lack of data, lack of access to data, and inability to use (Willoughby, 2022). Therefore, strengthening communication channels and methods is imperative to ensure that policymakers, urban planners, community leaders, and other stakeholders are equipped with the knowledge, understanding, and resources needed to develop and implement robust adaptation strategies (Ocampo-Melgar et al., 2016).

This demonstrates why research is necessary to understand the main challenges in the current communication strategies of sea level rise and cyclone risk to urban planners, as well as factors that may interfere with the level of integration of this information into urban planning, considering the lack of specific studies that examine the efficacy of science communication strategies in translating sea level rise and cyclone risk data into urban planning policies in Maputo. Furthermore, by improving the communication of sea level rise and storm surge risk, stakeholders can predict, prepare for, and respond to the effects of coastal hazards. This ultimately contributes to the city's ability to withstand and recover from these hazards, as well as achieve its goals for sustainable development (Uzochukwu et al., 2016).

2. Literature Review

2.1. The framework for Climate risk assessment in Maputo

2.1.1. Mozambique climate disaster risk profile

In Mozambique, the negative impacts of climate change are a constant reality as the country frequently faces extreme weather and climate events such as droughts, floods, and cyclones (Bacci, 2014). Mozambique's location, long and fragmented coastline, extensive lowlands, where the deltas of 13 major regional rivers, and high population density in coastal areas make it particularly susceptible to the effects of rising sea levels, cyclones, intense storms, floods and droughts (Hoque et al., 2019). The country's tropical climate, characterized by high temperatures and heavy annual rainfall, heightens the risk of coastal hazards (Sanyal and Shuvo, 2020), and the limited infrastructure and government capacity to address the impacts of climate change has increased its disproportionate vulnerability (Hoque et al., 2019). The country is highly vulnerable to climate change, ranking 154 out of 185 on the 2021 Notre Dame Global Adaptation Initiative (ND-GAIN) index (Mucova et al., 2021). Between 1980 and 2019, Mozambique was hit by 53 natural disasters, impacting up to 28 million people and resulting in a 5.5 percent reduction in GDP growth when extreme weather events occurred (Muhala et al., 2021). Despite having minimal greenhouse gas emissions, Mozambique's extreme poverty and dependence on natural resources have compounded the challenges brought by climate change (Hervey and Blythe, 2013).

2.1.2. Climate change impacts in Maputo

Many African coastal cities are currently facing serious threats from the direct and indirect impacts of climate variability and change (Mucova et al., 2021). Changes in temperatures, precipitation, and sea level are key indicators of these "stresses." Low-lying coastal cities, which are densely populated and of great ecological and economic significance, are at the greatest risk from the potential implications of climate change (Nhantumbo et al., 2023). Unfortunately, few, if any, African coastal cities are adequately prepared to handle the impacts of climate change hazards, particularly the rise in sea level and storm or cyclone events (Muhala et al., 2021). As a coastal city, Maputo is vulnerable to the hazards of climate change (Bacci, 2014). In 2010, the World Bank and Mozambique National Institute of Disaster Management (INGD/INGC) recognized Maputo Municipality as one of the areas in Mozambique that is highly susceptible to the effects of climate change (Matos et al., 2023). The direct consequences of climate-related threats in Maputo Municipality include the destruction of infrastructure such as roads, drainage systems, sewage, water and electricity systems, as well as public and private buildings and spaces (Zehra et al., 2019). This leads to a reduction in the quality-of-service provision for the municipality's residents (Chicombo, 2021). With most of the citizens in Maputo Municipality relying on subsistence activities that are sensitive to climatic risks, the economic losses due to climate-related risks and threats in Maputo Municipality are estimated at $50 million per year and are expected to rise in the future if appropriate adaptation measures are not implemented (Queface et al., 2011).

Table 1. Maputo's vulnerability to extreme events. Source: INE, 2008, in UN-Habitat, 2010.

Sector or area	Climate change related-event	Impact or consequences
Coastal zone and ecosystems	Tropical cyclones	Damage to coastal infrastructure, dunes, beaches and other natural features
	Rising sea level and storm flow	Increased erosion or damage to coastal infrastructure, dunes, beaches, and other natural features
		Loss of coastal wetlands, mangroves and other coastal habitats
		Higher costs for maintenance and expansion of coastal erosion controls (natural or man-made)
		Saltwater intrusion into coastal aquifers
		Higher risk of pollution from coastal hazardous waste sites
		Reduced effectiveness of sea walls
Transportation systems	Variations in temperature and heavy rainfall	Increased damage to road surface sand bridges
		Increased maintenance requirements for roadside/pavement
Wetlands and urban agriculture	Heavy precipitation	Increased risk of flooding
	Dry season	Crop failures, water scarcity, drying of water reservoirs, and stronger demand for irrigation
		Increased risk of habitat loss (mangroves), and salt intrusion
Human settlements and infrastructure	Tropical cyclones	Damage to housing and infrastructure
	Heavy rainfall	Damage to housing and infrastructure
		Need for new or upgraded flood and erosion control structures
		Landslides, road washouts and flooding
		Increased demands on storm water management systems and sewer overflows
	Rising sea levels	Reduced effectiveness of sea walls
		Damage to housing and infrastructure
Health, food and waste management	Heavy rainfall	Increase in vector-borne diseases (malaria, cholera, etc.)
		Need for new waste collection, management and treatment systems

While climate change assessment and impact studies are well-documented in Mozambique, they have mainly focused on the national (Artur and Hilhorst, 2012). This has resulted in insufficient adaptation plans and measures at the municipal level (Bacci, 2014). The effects of climate change are already significantly impacting ecosystems, infrastructure, people, and socio-economic values in different coastal areas and within the Municipality of Maputo (Boyd et al., 2014).

2.1.3. Rising temperatures

Temperature is a key climate indicator and significantly influences living conditions in many African countries (Arndt et al., 2012). In Southern Africa, temperatures are rising faster than the global average, with an observed increase of 2℃ (1.5–2.5℃) compared to the global warming range of 1.5℃ (0.5–1.5℃) over the past century (Ahmed et al., 2022).

The projected temperature rise in Mozambique by 2050 is estimated to be between 1℃ and 2℃nin all seasons and in all three regions, with the most significant increase ranging from 2.5-3℃ during the September-October-November (SON) season. Inland areas are expected to experience a larger temperature rise compared to coastal locations. The effects will be most prominent in the Gaza Province, north of the Tete Province, and parts of Niassa Province (Adelekan et al., 2022).

Table 2. Temperature Changes in Mozambique by 2050. Source: Adelekan et al., 2022. Calculations using GCM results (Commonwealth Scientific and Industrial Research Organisation (CSIRO), National Center for Atmospheric Research (NCAR), United Kingdom Meteorological Office.

	Global Dry CSIRO	**Global Wet NCAR**	**Moz. Dry UKMO**	**Moz. Wet IPSL**
Temperature changes (Celsius)				
North region	*1.23*	*1.89*	*1.37*	*1.47*
Centre region	*1.40*	*1.81*	*1.78*	*1.49*
South region	*1.51*	*1.58*	*1.66*	*1.36*

Historical data shows that in Maputo, most coastal locations experienced a rise of 0.32 °C in average annual maximum air temperature each decade from 1970 to 2006, while the average annual minimum temperature decreased by 0.04 °C per decade (Bacci, 2014). In the mainland of Maputo, the average annual maximum air temperature rose by 0.23 °C each decade, and the minimum temperature climbed by 0.33 °C per decade during the same period. Projections indicate that between 2046 and 2065, the average annual maximum air temperature in Maputo temperatures could increase by 2.1 °C, and the lowest temperature could rise by 2.2 °C. A warmer future climate will lead to a higher risk of more intense, frequent, and longer-lasting heat waves (Bacci, 2014). The heat wave that occurred in Maputo in March–April 2011, lasting over a week, is an example of the extreme heat events that may become more common in the future (Boyd et al., 2014). Additionally, due to the greater water-holding capacity of a warmer atmosphere, there is an increased risk of drying, as well as more intense precipitation and flooding. This has already been observed and is expected to continue, as rising global temperatures tend to cause longer and more intense periods of precipitation. Moreover, if the rise in temperatures results in higher water demand, it could negatively impact people's livelihoods and worsen water-related issues (Bacci, 2014).

2.1.4. Sea Level rise

Climate change-induced sea level rise is one of the main challenges for coastal lowlands with scenarios, including those compatible with the Paris Climate Agreement, predicting significant sea-level rise by 2100 (Bongarts Lebbe et al., 2021). Sea level rise and coastal flooding are projected to increase along the coast of East Southern Africa, with extreme total water levels (including relative sea level, storm surges, tides and high waves) increasing by between 20cm and 40cm by mid-century (Murphy et al., 2023). Projections for the rise in sea level reveal that the estimates for the Mozambican coast are greater compared to global estimates (~0.05 m) for all representative concentration pathways (RCPs) and shoreline retreat by 2100 is projected to be generally between 50m and 200m along most of the coast of Mozambique (Mucova et al., 2021; Murphy et al., 2023).

The rising sea levels and the projected 10% increase in storm surges will greatly raise the risk of flooding and significant damage along the coastline of Mozambique. This is particularly concerning for major cities and ports such as Maputo, Beira, Nacala, and Quelimane, as these areas are mostly comprised of low-lying coastal lands, river basins, coastal lagoons, and sand dunes (Nhantumbo et al., 2023). Predictions also point to disastrous effects of global sea level rise on populations, environmental services, and biodiversity, including negative impacts on infrastructure, livelihoods, coastal agriculture, important ecosystems, and fisheries (Rocha et al., 2020). Mozambique is anticipated to suffer large losses without effective coping measures, affecting its economy and coastal development (Neumann et al., 2015).

Projections also point to a reduction in wetland area of 1,318 km_2 based on the assumption that approximately 45% of coastal wetlands will be impacted. Approximately 55% of urban land located along the coast, 40% of the total land area along the coast, 24% of agricultural land along the coast, 51% of the population living in coastal areas, and roughly 55% of the coastal gross domestic product (GDP) are at risk of being lost (Mucova et al., 2021).

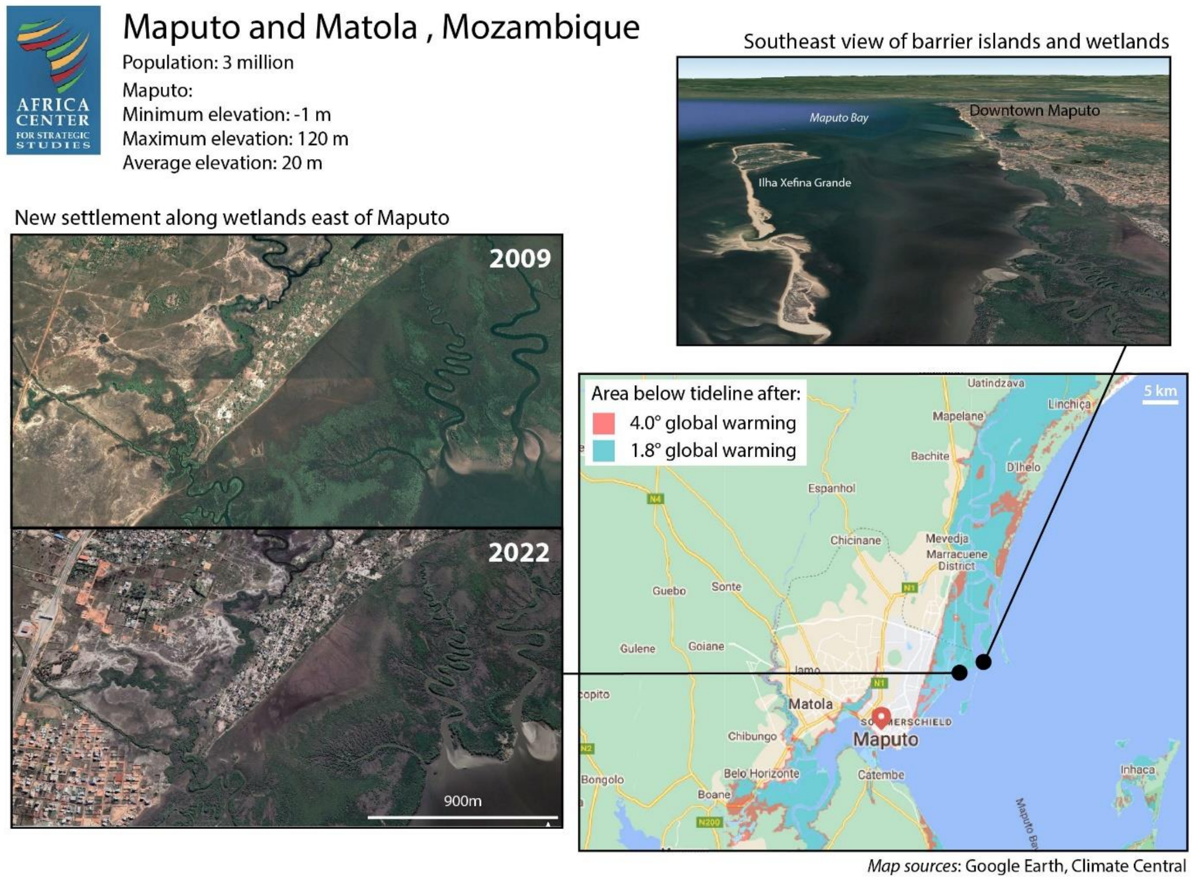

Figure 1. Evolution of urban settlements along wetlands exposed to SLR in Maputo. Source: Google Earth, climate central, 2022.

In Maputo, the sea may rise by 10 cm by 2030 (low scenario) and between 20 cm and 100 cm by 2060 (medium scenario) (INGC, 2009). The projected increase could have adverse consequences for coastal areas located at the lowest-lying areas of Maputo, which are the most populated areas, resulting in flooding, reduced agricultural output, and the destruction of local citizens' assets ((INGC, 2009; NAPA, 2007). The average sea level in Maputo may be also influenced by the total rainfall/runoff pattern of the catchment areas of the Incomati, Maputo and Matola River basins (INAHINA, 2008).

2.1.5. Flood

Flooding poses a widespread threat, endangering 1.81 billion people globally, with coastal cities particularly vulnerable and predicted damages exceeding USD 50 billion by 2050 (Neves et al., 2023). In Mozambique, extensive low-lying floodplains experience frequent and severe flooding, with significant events nearly yearly over the past decade. The 2000 floods in the southern and central regions resulted in 700 fatalities, displaced approximately 491,000 people, and caused millions of dollars in damage (Wiles et al., 2005). More recently, in 2023, Mozambique experienced unprecedented rainfall due to Tropical Cyclone Freddy, with over

18,500 square kilometres of land flooded, leading to the displacement of 9,892 people, 10 fatalities, and the destruction of 1,637 houses across six provinces (INGD, 2023). In 2024, Cyclone Filipo brought wind gusts of up to 120 kilometres per hour, with flooding affecting approximately 500,000 individuals (INAM, 2024).

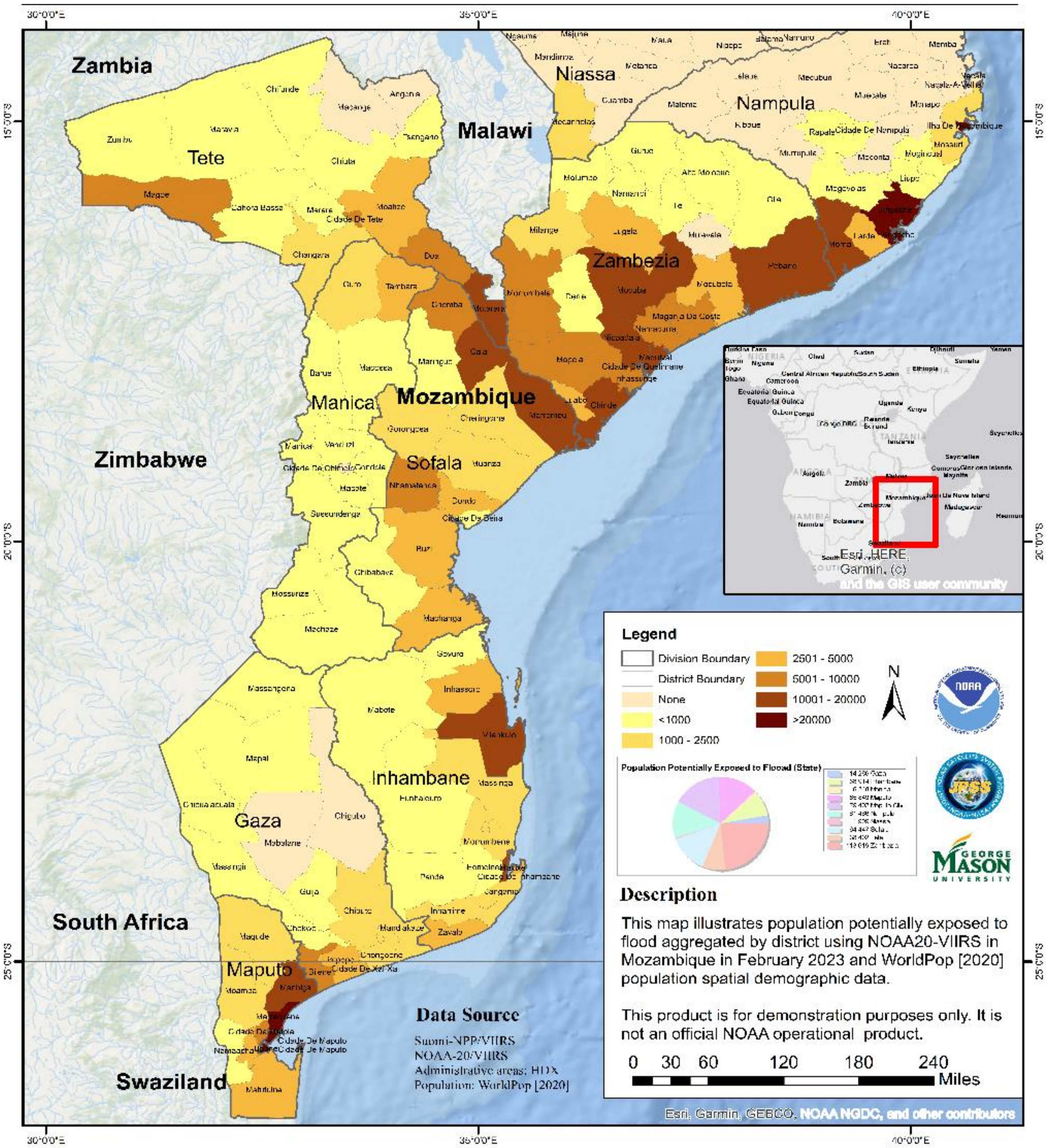

Figure 2. Population potentially exposed to flooding in Mozambique in February 2023. Source: *NOOA, 2023.*

The flood impact in Mozambique is greatest in coastal regions. The Provinces of Inhambane, Gaza, and Maputo are relatively exposed to the floods, whereas Sofala and Zambezia are the most affected (Arnall et al., 2013). In Maputo, heavy rainfall leads to significant flooding, and it is expected that climate change will worsen this problem in the region (Matos et al., 2023). The city's maximum altitude is 80 meters, and it has a southwest-northeast orientation with very gentle slopes (around 6%), which are more pronounced in the limited area of Costa do Sol. This topography leads to frequent flooding during heavy rain, particularly in the lower sectors and near the main watercourses.

The association between rainfall and storm surges heightens the likelihood of flooding. When it rains, a significant portion of the water runoff from the higher elevation of the city does not flow into the drainage system but rather gathers in the lower-lying area, resulting in frequent instances of flooding (Matos et al., 2023).

The city’s informal settlements are at high risk for flooding due to their inadequate infrastructure and location in low-lying regions (Zehra et al., 2019).These areas often house marginalized groups who have faced social, economic, and health inequalities, lack basic rights, and are isolated from other communities. They are commonly located in floodplains, steep slopes, and low-lying regions that are more prone to geophysical hazards, which are worsened by climate change (UN-Habitat, 2020).

A) B)

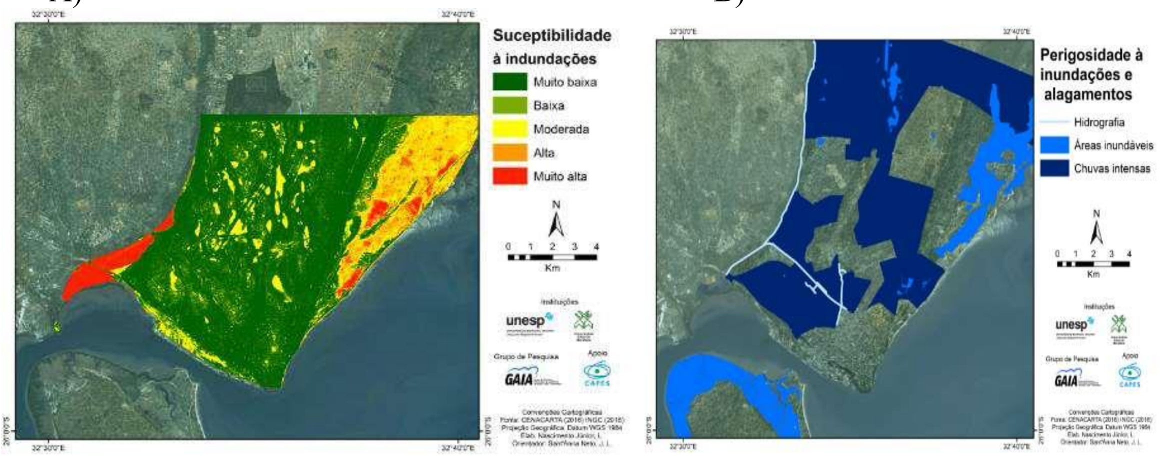

Figure 3. Map of flood susceptibility (A) and flood hazard (B) and the urban site in the city of Maputo (Nascimento Junior and Neto, 2021).

2.1.6. Cyclones

Tropical cyclones are among the most deadly natural catastrophes due to their extreme environmental destruction, economic decline, and human mortality (McCordic et al., 2024).

The South West Indian Ocean SWIO) region, situated in an active cyclone belt, is one of the main tropical cyclone areas in the world and the most cyclone-active area in the Southern Hemisphere and, usually experiences the formation of 10 to 12 tropical systems per year and several cyclones originating from this region can move towards the Mozambique Channel; however, not all of them make landfall in Mozambique (Charrua et al., 2021).

Mozambique's coastline is susceptible to cyclones during the rainy season, from November to April (Manhique et al., 2023). On average, two of them hit Mozambique annually, causing severe storm surges, waves, wind, and rainfall along the coast (Arndt et al., 2010; Kolstad, 2021). Cyclones also exacerbate the risk of seawater flooding, particularly from storm surges (Uamusse et al., 2020).

Table 3. List of cyclones that hit Mozambique in the period from 1983 to 2024 (Mutote et al., 2024).

Cyclone names	Years of occurrence	Maximum wind (km/h)	Number of people affected
Demoina	1983/84	100	35 000
Filao	1987/88	142	-
Nadia	1993/94	220	903
Bonita	1995/96	250	98 727
Lisette	1996/97	125	-
Eline	1999/00	215	26 101
Gloria	1999/00	42	-
Atang	2001/02	58	-
Delfina	2002/03	100	268 129
Japhet	2002/03	140	105 231
Flavio	2006/07	222	194 112
Jokwe	2007/08	150	166 127
Dando	2011/12	220	15 352
Funso	2011/12	200	-
Irina	2011/12	100	4 550
Dineo	2016/17	155	173 990
Desmond	2018/19	130	64 699
Idai	2018/19	280	1 514 662
Kenneth	2018/19	230	550 959
Chalane	2020/21	111	289 987
Eloise	2020/21	165	73 254
Guambe	2020/21	155	469 831
Ana	2021/22	130	185 429
Gombe	2021/22	230	736 015
Dumako	2021/22	165	23 733
Jasmim	2021/22	-	-
Freddy	2023	183	1 180 000
Alvaro	2024	74	-
Filippo	2024	111	57 178
Hidaya	2024	148	-

The data indicates that in the period from 1983 to 2024, Mozambique was impacted by more than 26 tropical cyclones, which resulted in 6,249,273 people affected, 3,004 injured and 1,352 deaths (Kolstad, 2021). Since 1992, there has been a rise in the frequency of increasingly devastating cyclones and recent modelling studies indicate that tropical cyclones may experience even more increased severity in the future, characterised by elevated wind speeds and more intense precipitation (Boko, 2007). Notably, the cyclones that occurred in the years

1999/2000 (TC-Eline), 2002/03 (TC-Japhet), 2007/08 (TC-Jokwe), 2011/12 (TC-Dango), 2016/17 (TC-Dineo), 2018/19 (TC, category 4-Idai and Kenneth), 2020/21 (TC, category 2-Eloise), 2022 (TC-Gombe), 2023 (CT, category 3-Freddy) and 2024 (TC- Filipo) stand out in demonstrating the evolution of the intensity of these phenomena (Singh Schoenmakers, 2023).

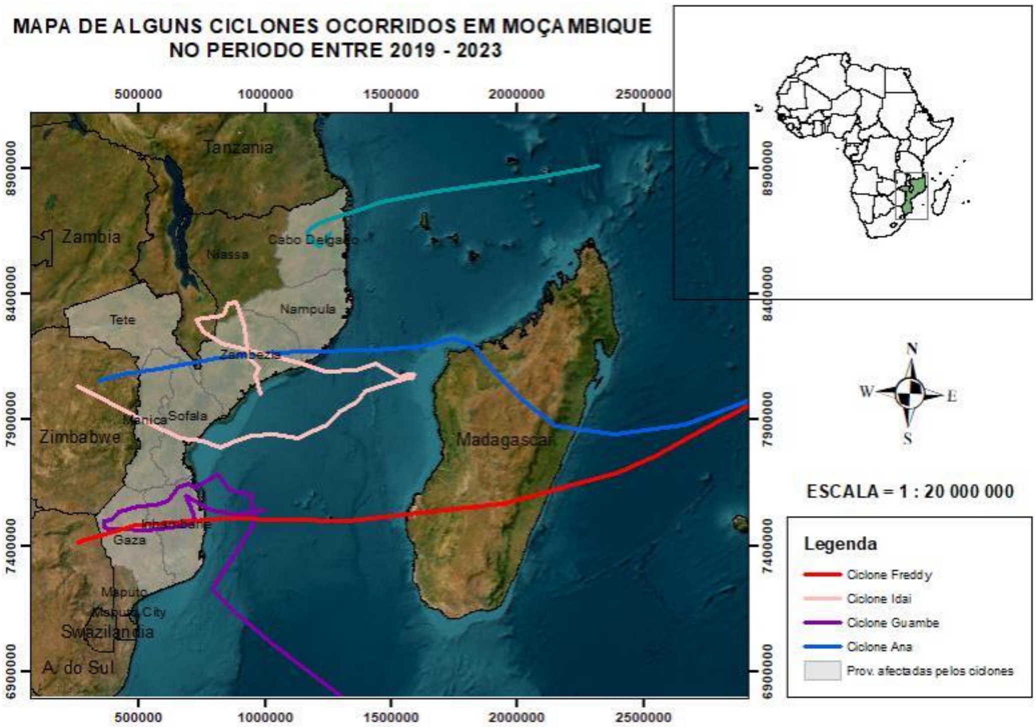

Figure 4. Tracks of cyclones that hit Mozambique between 2019 and 2023 (Mutote et al., 2024).

The extensive damage caused by Cyclone Idai in 2019, one of the deadliest storms on record in the southern hemisphere, which resulted in the flooding of 2,515 km$_2$ of the low-lying plains in the central region of the country, serves as a poignant reminder of the magnitude of the issue (Kolstad, 2021). Tropical Cyclone Freddy, one of the longest-lasting tropical cyclones on record, struck Mozambique twice in 2023, causing widespread flooding in Zambezia Province, which contains approximately 25% of the nation’s agricultural land and contributes nearly a third of the country’s staple food production (UNDRR, 2024).

The Central region, particularly Sofala Province, is disproportionately affected by cyclones, experiencing six events in just 16 years, with its vast low-lying terrain making it prone to flooding and storm surges that endanger 40% of its population living in high-risk areas (Kolstad, 2021; McCordic et al., 2024). Nampula and Inhambane provinces, though less frequently hit by cyclones, still endure severe cyclone wind impacts on about 20% of their total population (McCordic et al., 2024). While Maputo is not the most cyclone-prone area, projections indicate that storm surges could elevate sea levels in its low-lying coastal districts by at least 1.1 meters by 2050, threatening critical urban (Nhantumbo et al., 2023). It is anticipated that the combination of rising sea levels, high tides, and storm surges will lead to a significant 2.7-meter increase in the coastal areas of southern Mozambique, including Maputo, between 2046 and 2065, particularly affecting the population in urban areas and informal settlements (Neumann et al., 2015; J. Nhantumbo et al., 2023).

2.2. Maputo Urban dynamics and climate hazards

2.2.1. Population growth

Population growth and development are key drivers of change in coastal areas. They exert significant pressure on coastal ecosystems and natural resources, while also increasing the exposure of large numbers of people and assets to existing climate hazards, sea-level rise, and related effects. This substantially raises levels of risk and vulnerability along coastlines (Neumann et al., 2015). There has been significant population growth during the 2nd millennium, both globally and specifically in Africa, particularly in Mozambique (Neves et al., 2023). Mozambique had 12,185,777 inhabitants in 1980, rose to 16,141,837 in 1997, and grew to 20,548,749 in the 2007 census. Data from the 2017 census indicate a population of 27,909,798 (Leonardo Pontes Teixeira and Souza Pessoa, 2021).

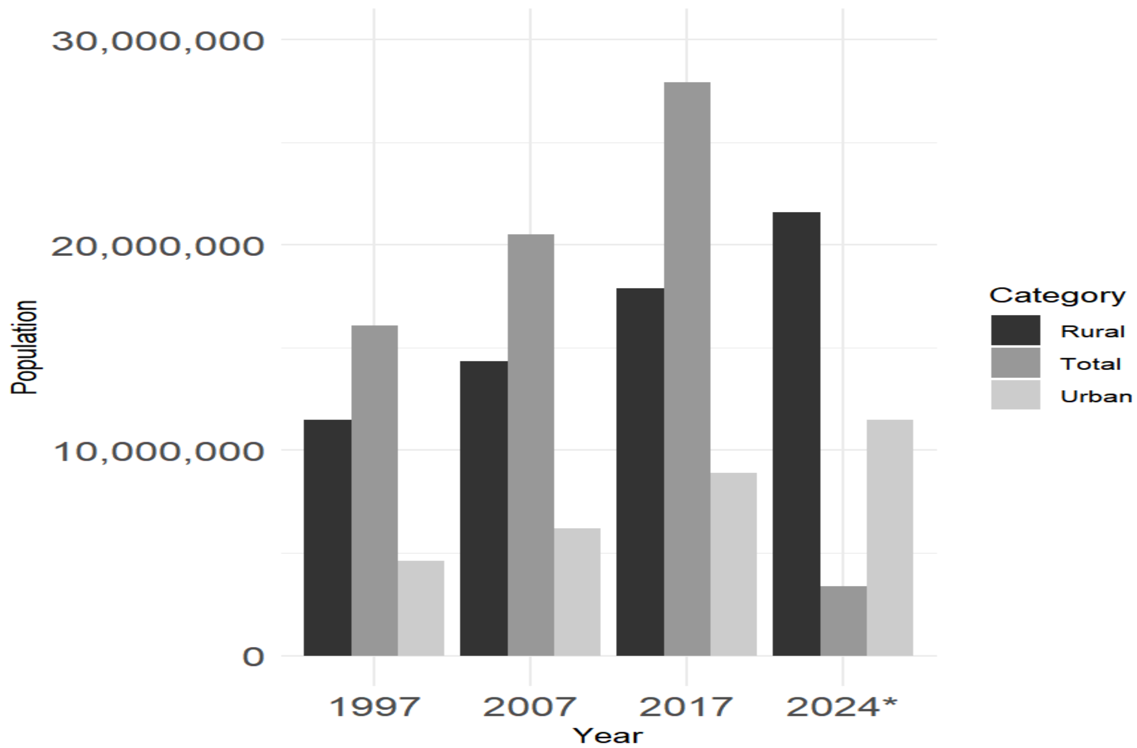

Figure 5. Urban and rural population in Mozambique in the 1997-2017 censuses and current population rates. Sources: (INE, 2019); (UN-Habitat, 2020).

The annual population growth rate is 2.85 per cent, and the World Bank forecasts that 50 to 60 per cent of the Mozambican population will be living in cities by 2050, totalling 30-36 million urban residents (Neves et al., 2023). While urban growth is mainly caused by natural population growth (2.7 per cent), rural migration contributes 0.8 per cent growth per year, often with spikes caused by natural disasters, conflicts, or the resettlement of the population as a result of economic activities (Udelsmann Rodrigues, 2019).

After the Mozambican war ended in 1992, some people returned home while others stayed in fragile settlements in Maputo, Matola, Beira, Nampula, Quelimane, Tete, and other provincial capitals and towns (Maloa, 2019). The ongoing demographic expansion and spatial distribution of Maputo city was driven by the pursuit of security by individuals migrating from various regions in the south (primarily Gaza and Inhambane) as well as other provinces within the country (Leite Dos Santos Viana et al., 2013). According to the UN Population Division's average projections, the country's population is expected to reach 68 million in 2050 (growing more than 10 times in 100 years) and 135 million in 2100 (growing about 20 times in 150 years).

Table 4. Mozambique's main cities population in the 1980-2017 census (INE, 2019).

Main cities	Population			
	1980	**1997**	**2007**	**2017**
Maputo	555 000	985 584	1 099 102	1 101 170
Matola	206 000	430 280	675 422	1 616 267
Xai-Xai	44000	103 251	116 343	143 128
Inhambane	54 990	54 147	63 867	79 724
Beira	239 744	412 588	436 976	533 825
Chimoio	74 372	177 608	238 976	372.821
Tete	47 000	104 832	152 909	305 722
Quelimane	62 174	153 187	192 876	349 842
Nampula	156 185	314 956	477 900	743 125
Nacala	80 426	164 309	207 894	225 034
Lichinga	41 000	89 043	142 253	213 361
Pemba	43 000	88 149	141 316	201 846

2.2.2. Rapid Urbanisation

A report by the United Nations Population Fund (UNFPA) projects that by 2030, the urban population on the African continent will reach 80 percent. This rapid urban growth raises important considerations regarding the form and structure of the process (UNFPA, 2017). Mozambique's urban population, estimated at 38% (World Bank and United Nations - World

Urbanisation), is still relatively low, but Mozambique is urbanising rapidly. Urbanisation is happening all over the country - both in areas that are now considered urban as in areas currently considered rural (Maloa, 2019). The most predominant characteristics of urbanization in Mozambique are urban duality, rurality in the urban, informality and demographic growth, as illustrated in Figure 7.

1. ***Urban duality:*** segregationist and racist values structure Mozambican cities into two compartments: on the one hand, neighbourhoods configured in orthogonal plans, with vertical buildings, service networks, commerce, basic sanitation, electricity supply, drinking water, telecommunications, etc.; on the other hand, neighbourhoods structured in horizontal housing, precarious in terms of infrastructure and urban services. Dual colonial urbanisation became known as the binomial "cement city" versus "reed city", in other words, two "cities" coexisted in the same urban space, experienced differently by two types of residents: the "settlers" and the "colonised"
2. ***Rurality in the urban***: where the low-income population prevails, especially those who migrate from rural to urban areas in search of survival, as a way of coping with the difficult urban life, and end up adapting rural attitudes, habits and behaviours. Although it appears to be transitory, this characteristic persists in almost all Mozambican cities.
3. ***Informality of access to urban land:*** In Mozambique, land belongs to the state. Individuals can claim land rights based on historical occupation, and oral testimony is recognized as evidence.
4. ***Rapid demographic growth in urban areas***: influenced by the rural exodus and high birth rates. The United Nations Development Programme (UNDP, 2007) calculated that in 2007, the demographic growth rate for the urban population would be 34.5% and estimates that by 2025, the rate will be 50%.

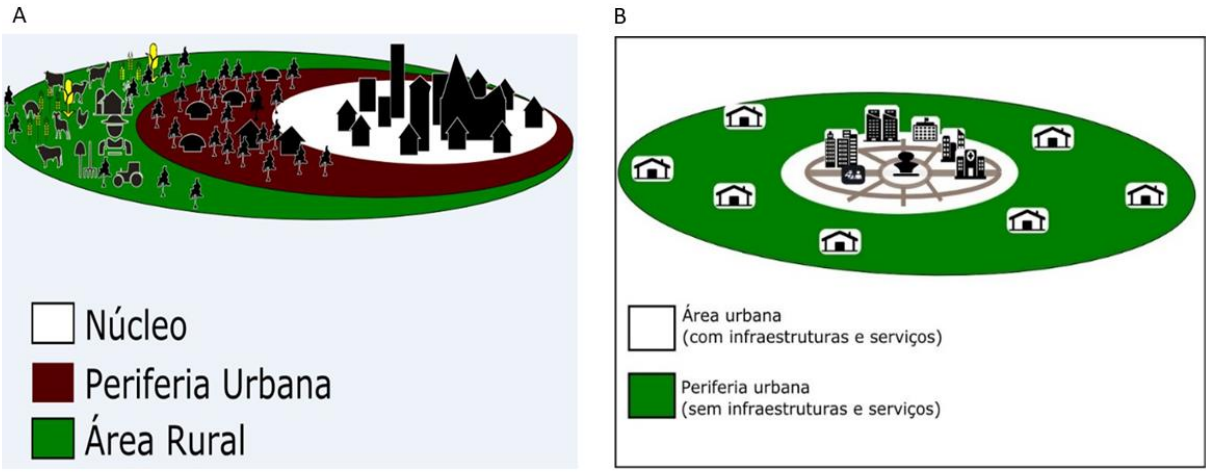

Figure 5. Image (A) illustrates the pattern of urban sprawl in Mozambique, predominantly occurring on the periphery of cities. Image (B) presents a schematic representation of the spatial dynamics of Mozambican urbanization, highlighting the extensive peripheral expansion that drives urban growth. The white circle denotes the urban area with services (Maloa, 2019).

Thus, in the classification of the Mozambican urban network, three categories were identified, which are as follows (Chicombo, 2021):

- *National and Regional medium-sized cities* - these three upper strata of the network are made up of 13 urban centres with the exception of the greater Maputo region, the country's capital, which is a metropolitan urban agglomeration.
- *Regional urban centres* - these comprise three urban centres, one of which, as already mentioned, is a metropolitan area.
- *Sub-regional centres* total 11 urban centres.

The country's urban network is made up of 53 urban centres, 12 of which are medium-sized urban agglomerations. The 12 medium-sized urban agglomerations involve around 50 municipalities (Leite Dos Santos Viana et al., 2013).

All municipal urban centres (cities and municipal towns) in Mozambique lack a defined structure and have disorganised urban settlements in peripheral expansion areas called 'suburban neighbourhoods' also called 'bairros' that show varying degrees of urbanization, land use, and housing stability and none have satisfactorily resolved the planning and management of urban land, so the precarious model of occupation prevails, presenting many difficult-to-solve problems including inadequate equipment and infrastructure, limited access to education, civic protection, and health care, environmental degradation, high unemployment, and sectorization of the informal economy and urban poor (Maloa, 2019).

In this context, it can be said that Maputo's current urbanisation can be characterised by the capitalist type of dispersed city, which comprises land occupation with low population density in peripheral areas of the urban core, with the consolidation of nuclei that combine different forms of land use and land cover in territorially discontinuous forms (Maloa and Júnior, 2019). The scattered urbanisation in Maputo is mostly driven by peripheralization and environmental deterioration, resulting in the formation of regions commonly referred to as 'informal settlements'. Informal settlements are home to the majority of Mozambican city residents, with 80% living in such areas covering 70% of urban areas. This model synthesises and articulates the structure of the Mozambican reed city, leading to the emergence of informal communities. These settlements are widespread across the urban area, reflecting the prevailing conditions in the region (Maloa and Júnior, 2019).

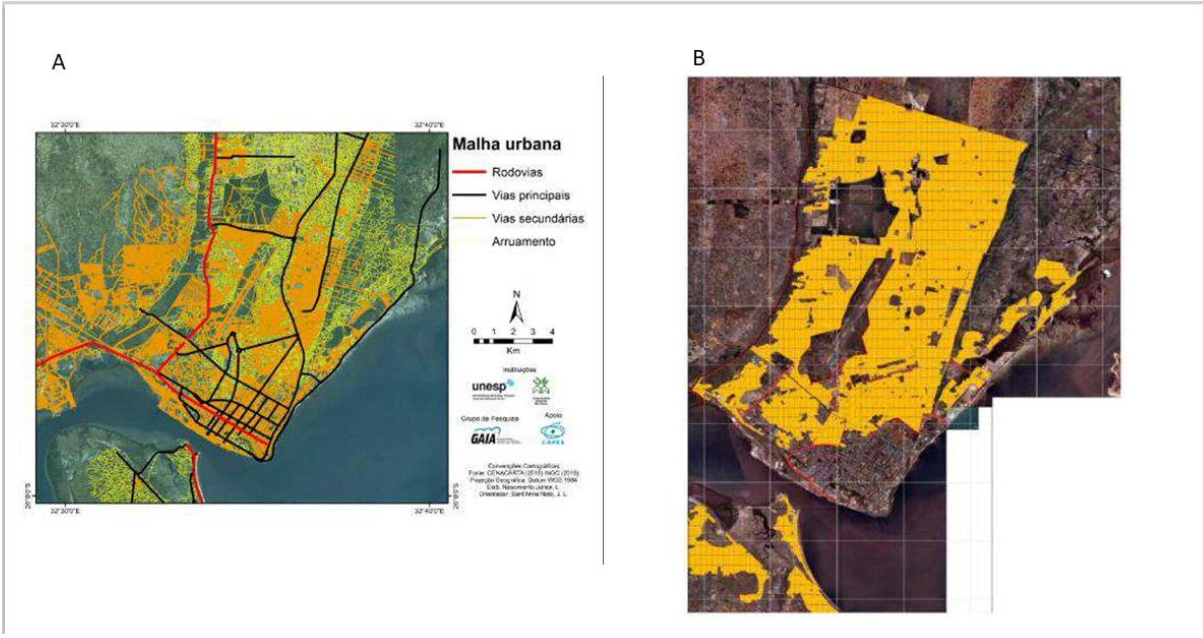

Figure 5. Maputo Urban network and streets (a); (b)Informal settlements (yellow area) in Maputo. Source: Nascimento Junior and Neto, 2021.

The increasing number of people migrating to the urban areas in Maputo will further exacerbate the impacts of climate-related hazards and the vulnerability of the socio-ecological urban system due to rapid coastal urbanization, as Maputo urban areas are classified as highly sensitive to climate extremes and having the highest exposure to sea level rise-driven settlements, particularly under less effective governments (Sterzel et al., 2020).

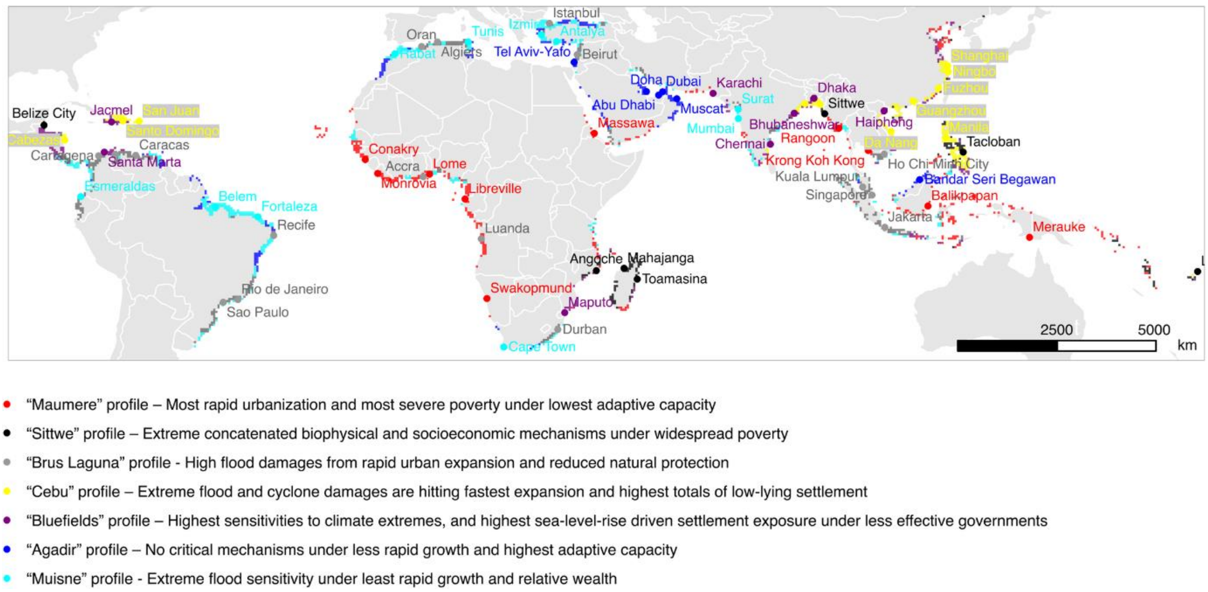

Figure 6. Maputo profile to climate extremes (Bluefield profile) – highest sensitivities and exposure to climate extremes (Sterzel et al., 2020)

Notable observations reveal that the southern part of Maputo city, often known as the cement city, presents a greater level of urban development (see Figure 8). Although the development on the coastline has only increased somewhat, these findings still indicate a substantial level of development on a coastline that is susceptible to storm surges and sea level rise (Willoughby, 2022).

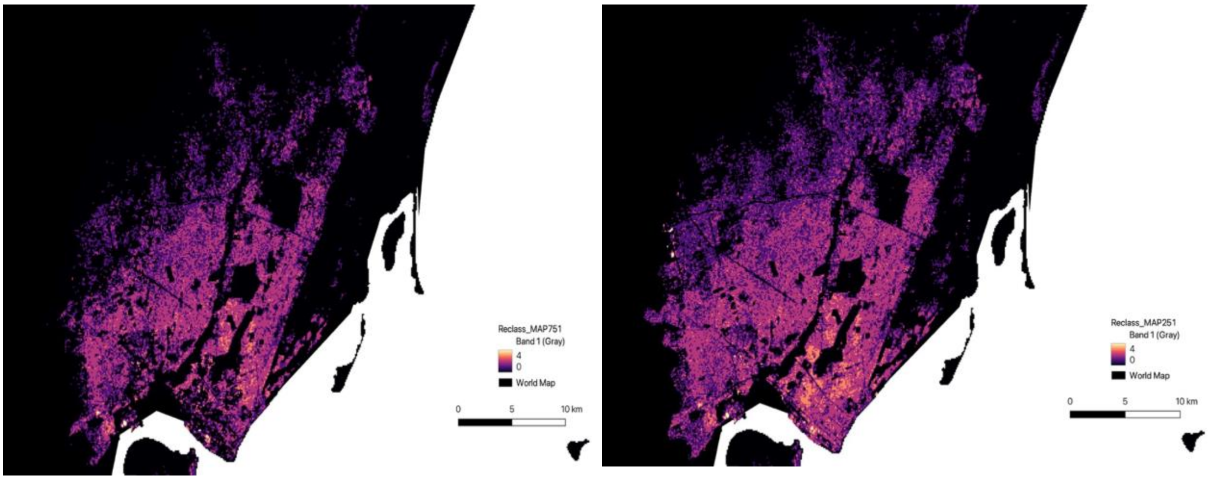

Figure 7. Remote sensing images showing urban built-up surface area in Maputo 1975 (left) and projected for 2025 (right). Low surface urbanisation is dark purple, while high urbanisation is bright yellow (Willoughby, 2022).

The rapid increase in urban population usually makes urban populations more vulnerable to extreme weather events due to inadequate urban management (Neves et al., 2023). This vulnerability is further intensified by urban expansion into high-risk areas, sea-level rise, and the concentration of poor populations in low-lying and densely populated informal settlements (Sterzel et al., 2020). Additionally, unchecked urban expansion and unregulated development leads to the degradation of flood-regulating ecosystems, such as wetlands (Merkens et al., 2016).

2.3. Urban planning and climate adaptation

2.3.1. Climate adaptation and adaptive capacity

Climate adaptation involves reducing risks that have not been avoided by mitigation initiatives, both locally and globally. Urban planning, a future-focused discipline, plays a crucial role in determining land use in cities and contributing to future resilience to climate risks. It involves professionals and strategic planning tools, addressing climate mitigation and adaptation through understanding the local urban area (Addaney and Cobbinah, 2019; Pasquini, 2020).

Within the realm of climate adaptation, urban planning can be approached in two primary ways: autonomous (or reactive) and planned (or proactive) (UN-Habitat, 2020). While the latter approach is considered the most optimal, as it aims to prevent or minimise the occurrence of climatic events, the former approach is still more commonly employed and is primarily reactive in nature, responding after the climatic impact has already taken place (Zhai and Lee, 2024). Although urban planning cannot address all impacts and consequences of climate change, with planning systems and regimes that promote sustainable urban environments, it has the potential to contribute to the UN SDGs (Pasquini, 2020).

Adaptation can occur at various levels, utilizing the available capacities of the entities involved at each relevant level. Therefore, many studies on adaptation have evaluated governance capacity and its associated limitations and facilitators. Addressing climate change through mitigation and adaptation also involves changing development principles and practices, particularly governance systems (Giordano et al., 2020). This presents additional challenges for developing countries, especially in addressing urban governance in areas such as planning, financing, and management. The key challenges faced by African cities in adapting urban planning to climate change include vulnerability, expansion of informal settlements, and poverty (Pasquini, 2020). Incorporating social, institutional, economic, and environmental factors into adaptation planning is necessary, and innovative approaches to boosting adaptive capacity and resilience are called for (Addaney and Cobbinah, 2019).

Vulnerability and resilience are important distinct concepts interconnected through adaptive capacity. Resilience is often seen as a positive aspect, while vulnerability and adaptive capacity are part of the concept of disaster (Zhai and Lee, 2024). The processes of exposure, sensitivity, and adaptive ability are interconnected and vary with scale, location, and time (Bongarts Lebbe et al., 2021). Vulnerability and resilience are not opposites but represent different ends of a continuum, with vulnerability indicating unfavourable results and resilience representing positive outcomes. In the context of climate change, vulnerability is seen as a consequence of exposure to risks and capacity for adaptation (Giordano et al., 2020). Resilience encompasses both outcomes and processes and aims to create a climate-resilient society. Disaster resilience involves not only bouncing back from a disaster but also proactively rebuilding and adjusting to handle future calamities (Zhai and Lee, 2024). Adaptation is a proactive response to reduce risks or negative effects, while resilience is a reactive response to continuous dangers. Long-term adaptation and short-term adaptation are divisions of the adaptation process. Overall, resilience, vulnerability, and adaptive capacity are interconnected and play a crucial role in understanding and addressing the effects of disasters and climate change (Zhai and Lee, 2024).

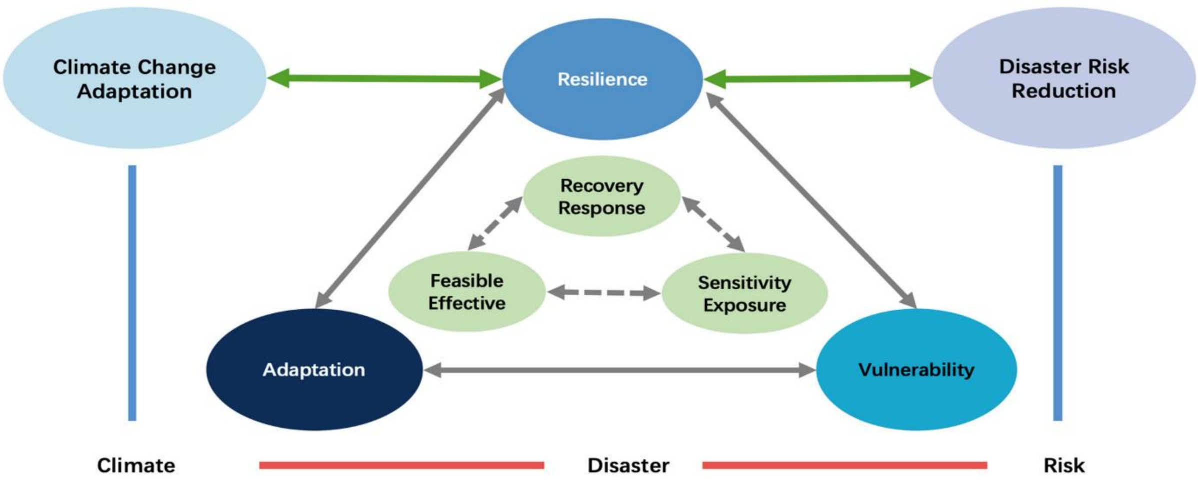

Figure 8. Links between vulnerability, adaptation, and resilience (Zhai and Lee, 2024).

2.3.2. Urban climate adaptation in Mozambique

The structure urban climate adaptation encompasses cognitive issues, resources, organisational variables, political aspects, and urban planning (see Figure 10) (Addaney and Cobbinah, 2019). Urban planning, encompassing activities such as land regularisation, housing policy, and the development of urban infrastructure, is widely recognised by scientific and professional communities as having a significant impact on climate adaptation, both in positive and negative ways (McClure and Baker, 2018). Integrating planning horizons and climate change scenarios is an intricate matter for cities, specifically the difficulty of adapting planning models that rely on past data and trend analysis to the intricate and uncertain nature of climate change, which may necessitate significant and transformative modifications (Biesbroek et al., 2018), which can be a challenge in Mozambican cities as it might involve implementing low-cost technology and also organizing groups to elevate their voice to the city-level policymakers. Aligned with risk perception, practitioners', planners', and decision-makers' awareness of the urgent need to promote adjustments to minimize climate effects is a critical cognitive factor that affects adaptation (Runhaar et al., 2018).

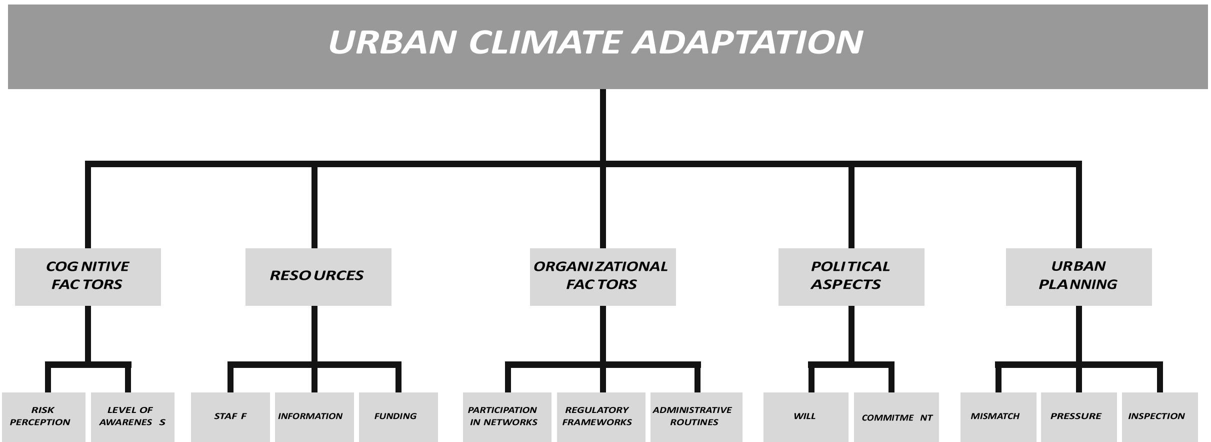

Figure 9. Structure of Urban Climate Adaptation (Addaney and Cobbinah, 2019).

As a Least Developed Country in the United Nations Framework Convention on Climate Change, Mozambique developed a National Adaptation Programme of Action (NAPA) in 2007 to identify the areas most susceptible to climate change and propose immediate measures to facilitate adaptation to these pressing concerns (Broto et al., 2015). The adaptation measures include: (i) strengthening an early warning system; (ii) developing capacities of agricultural producers to cope with climate change impacts by reducing soil degradation due to inappropriate agricultural practices; (iii) reducing climate change impacts in coastal zones via dune erosion control and mangrove restoration; and (iv) improved management of water resources through updated water infrastructure and establishment of water sharing agreements (Artur and Hilhorst, 2012).

However, there are several institutional barriers hindering efforts when it comes to urban climate adaptation (Broto et al., 2015). These barriers include inadequate incorporation of activities in management plans, limited implementation of local risk management committees at the community level in both air and land environments, excessive bureaucracy, and poor communication between different levels of government administration (Castán Broto et al., 2013). Other challenges include financial constraints, inadequate staff training for handling extreme situations, insufficient investment in research in institutions, subpar quality of technological devices used by meteorological services, and significant challenges in municipal-level territorial planning (Mutote et al., 2024). Moreover, the current approach to urban adaptation has primarily focused on identifying impacts through scenarios, risk, and planning, with limited consideration given to broader vulnerability concepts (Keskitalo et al., 2012), as an example, the urban adaptation option identified by the INGC for high risk/high impact that include:

- Improving sustainable urban drainage systems;
- Constructing near shore breakwaters;
- Developing a rapid reestablishment plan for financial transactions and,
- Generating solar energy at tourist facilities to reduce energy dependence

This approach often results in hard adaptations centred on technology, as reflected in the relatively narrow scope of climate change activities being carried out in cities globally (UN-Habitat, 2020), and despite efforts by the municipality to prioritize actions related to potential climate change, there is no evident methodology or actions in place to engage with communities in Maputo within their risk/hazard framework (Zehra et al., 2019)

2.4. Climate Science Communication

2.4.1. The role of effective science communication

Translating scientific knowledge into adaptive decisions requires effective science communication (Requier et al., 2020). This involves making complex, technical information understandable and relevant to diverse audiences, enabling them to respond to environmental changes (Joubert, 2001). To achieve this, science communicators must address their audience's needs, values, and perspectives, ensuring accessibility and relevance (Chu and Schenk, 2017). This chapter describes and explains the role of science communication to advance environmental education on climate change with a special reference on Africa being one of the regions suffering from the effects of climate-induced disasters and risks in the increased anthropogenic effects of modern development. It is argued that scientists are poor communicators on what they do, and hence, are often misunderstood by the media and society. This then calls for attention to be paid with regards to science communication, which has to be packaged in ways that make it easier for the generality of citizens to interpret and understand. Efforts in this regard are made possible through environmental education, which has proved to be useful in the discourse of disaster risk management in different parts of the world. The buttressing methodological philosophy to this chapter is applied systems approach. Critical areas of reference are health and diseases, resilient communities, coastal adaptation, and farming practices and technologies (Chirisa and Matamanda, 2022).

By employing evidence-based strategies and leveraging multiple communication mediums, science communicators can enhance their message's impact and empower communities to make informed decisions (Chirisa and Matamanda, 2022). Using diverse, trustworthy sources while avoiding plagiarism through proper attribution is essential. Effective communication bridges the gap between scientific knowledge and adaptation decisions, fostering understanding of climate change impacts and the necessary actions to mitigate and adapt to them (Joubert, 2001).

A key challenge is the knowledge-action gap in climate change communication, which arises from difficulties in translating scientific understanding into practical measures. Climate change is a multifaceted issue, encompassing environmental, social, economic, and political dimensions (Chu and Schenk, 2017). Thus, communicators must address these societal aspects and connect scientific insights with actionable steps (Chirisa and Matamanda, 2022). Interdisciplinary approaches and stakeholder engagement are critical to bridging this gap and science communicators can provide context and clarity, equipping individuals with a thorough understanding of climate-related risks and opportunities, and enabling informed and proactive decision-making (Requier et al., 2020).

2.4.2. Climate science and Urban practice

There is a growing global interest in addressing the implications of climate change in urban areas and coastal regions. Climate change-responsive urban settlements and infrastructure require research and urban planning (Sterzel et al., 2020). Climate knowledge is not automatically used to address risks and effects and merging scientific and stakeholder knowledge is difficult (Dessai and van de Sluijs, 2007). The challenges decision-makers encounter in comprehending and applying climate scenarios and uncertainty information, as well as assessing the policy consequences of uncertainties, are extensively documented, including:

Lack of context: Researchers and urban policy and decision makers often have different goals and conflicting ideals. They operate under distinct labor and reward systems. The policy cycle and knowledge creation cycle do not align. Policy cycles are influenced by elections and move faster than the progress of scientific research. Research is typically conducted on a project basis, contrasting with the ongoing engagement of local stakeholders. Researchers often underestimate the complexity of policy, assuming it is a rational and sequential process, when in reality, it is irrational and repetitive (Chirisa and Matamanda, 2022).

Mismatches between supply and needs: Scientists may overlook the "big picture" due to increased specialization, resulting in their focus being narrow and in-depth. Local stakeholders often prefer broader perspectives and adaptable solutions. As a result, research on adaptation may not always produce relevant knowledge that aligns with the needs, interests, and capabilities of decision-makers and implementers involved in adaptation (Requier et al., 2020).

Improper inclusion of local stakeholders in transdisciplinary research might lead to 'stakeholder fatigue'. Dialogues lacking tangible rewards will disillusion stakeholders and deter further engagement. Research plans often fail to assess local stakeholder participation levels. Effective implementation of stakeholder participation must be tailored case by case (Lipscomb et al., 2024).

Conflicting interests among non-academic players: Urban planning is complex, with competing interests from stakeholders, including provinces, municipalities, housing organizations, homeowners, and private corporations, hindering integration (Giordano et al., 2020).

Inadequate integration strategies: There is a need to connect scientific information with stakeholder values and interests by integrating knowledge, translating scientific climate information, and communicating with stakeholders, a function often overlooked (Ocampo-Melgar et al., 2016). Studies indicate that such drawbacks have had major implications for climate science application at various scales within urban areas, however, research information can be integrated and implemented into the practice of urban planning by (Joubert, 2001; Ocampo-Melgar et al., 2016; Chu and Schenk, 2017; Giordano et al., 2020; Chirisa and Matamanda, 2022):

Developing user-friendly interfaces: tools and interfaces that are easily accessible and understandable for urban and coastal planners that can provide them with the necessary climate adaptation research information in a format that is usable and applicable to their specific planning needs (Requier et al., 2020).

Facilitating collaboration and knowledge sharing: Collaboration among different stakeholders, such as planners, researchers, policymakers, and community members, is vital for effective urban and coastal planning. This collaboration can be facilitated through platforms, workshops, and other means of information exchange, which promote the integration of climate adaptation research into planning practices.

Building capacity and awareness: Urban and coastal planners need to be equipped with the knowledge and skills to effectively utilize climate adaptation research in their planning processes (Giordano et al., 2020).

Establishing institutional support: It is essential to have supportive institutional frameworks and policies in place that recognize and prioritize the integration of climate adaptation research into urban and coastal planning (Zhai and Lee, 2024).

Investing in resilient infrastructure: Climate adaptation research can inform the design and construction of infrastructure in urban and coastal areas. By incorporating climate adaptation measures, such as flood protection or green infrastructure, into the planning and implementation of infrastructure projects, cities and coastal areas can reduce their vulnerability to climate change impacts. By incorporating climate adaptation research into urban and coastal planning, we may improve planning decisions and strengthen cities' and coastal areas' climate change resistance (Chu and Schenk, 2017).

This chapter has emphasized the risks posed by coastal hazards in Mozambique and Maputo, as well as the vulnerability of urban residents as aspects of science communication. Effective climate science communication is necessary to ensure urban adaptation practices; however, it’s important to identify how to translate this information into adaptation practices (Palm and Bolsen, 2022).

3. Methodology

3.1. Study area

Mozambique is situated on the eastern coast of Africa between latitudes 10°20'S to 26°50'S. The country is bordered by the Indian Ocean to the east and by South Africa, Swaziland, Zimbabwe, Zambia, Malawi, and Tanzania to the south, west, and north, respectively (Artur and Hilhorst, 2012). The Mozambican coastline, which spans a length of 2,770 km, can be divided into three distinct regions: a sandy coast in the south, estuary areas in the central parts, and a coraline zone characterized by coral limestone in the northern half of the country. The country's coastal zone includes nine of the country's eleven provinces, namely: Cabo Delgado, Niassa, Nampula, Zambézia, Sofala, Inhambane, Gaza, Maputo Province, and Maputo City. Additionally, 40 of the 128 districts and 10 of the 23 cities in the country are situated within the coastal zone, meaning that about 60% of the Mozambican population lives in these regions (Charrua et al., 2021).

Maputo is the capital of Mozambique and a port city located in the extreme south of the country, at 26° southern latitude and 32°-35°eastern longitude on the coast of the Indian Ocean in Southern Africa (Barros et al., 2014). The city sits on a platform of Pleistocene red sand alternating with alluvial soils of poor structure in the lower regions at the confluence of three rivers – Maputo, Umbeluzi and Incomati. Maputo is characterised by a tropical humid climate, with two distinct seasons – hot and rainy (October – March) and cool with little precipitation (April– September) (Boyd et al., 2014). The average annual temperature is 23ºC, with its highest temperature in February at 27°C and lowest in July, and since the ocean influences, the thermic amplitude is low (Bacci, 2014). The climate is influenced by the Indian Ocean, especially the sea currents of the Mozambique Channel.

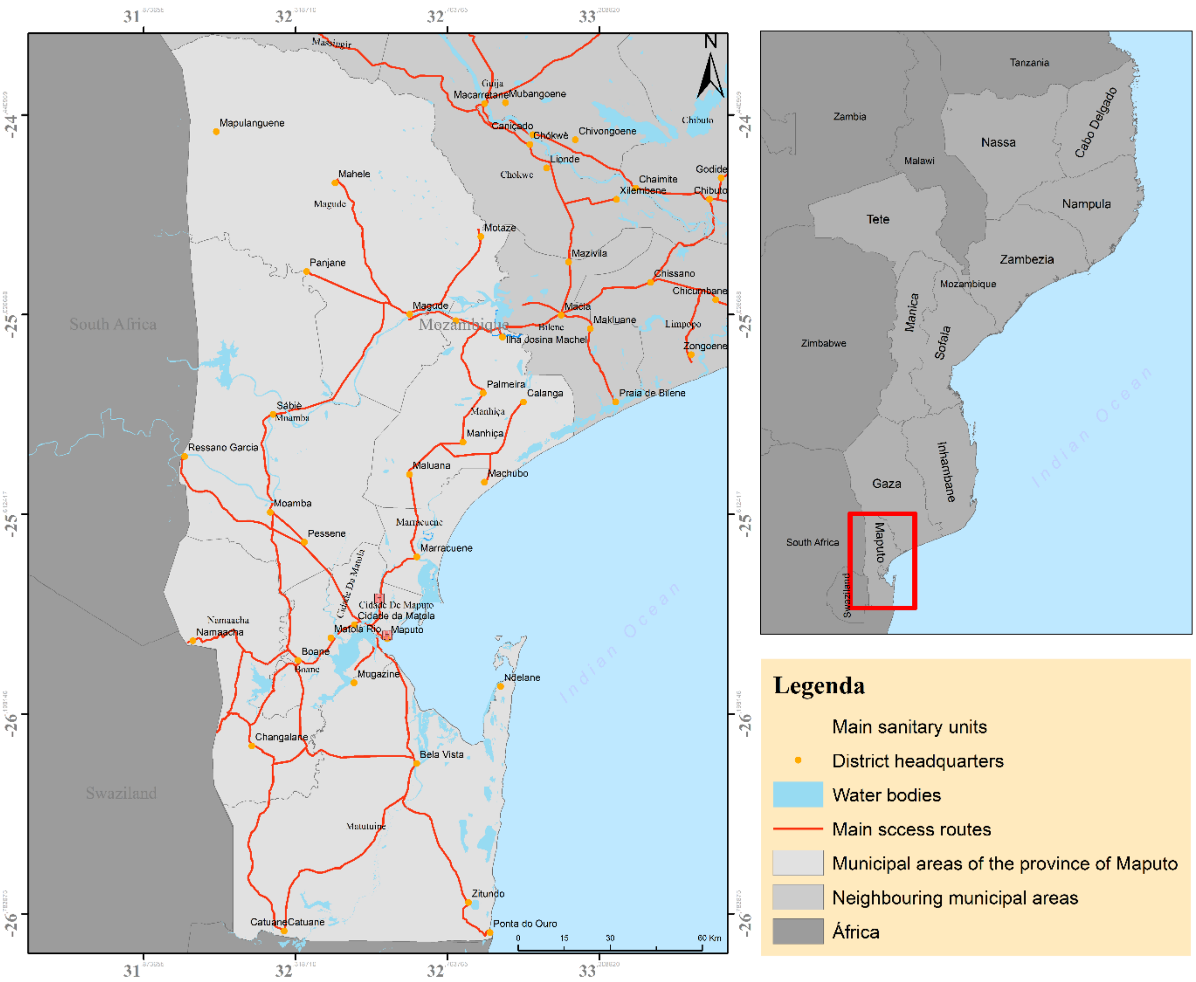

Figure 10. Study area, Maputo- Mozambique.

The Metropolitan Area holds great political and commercial significance in Mozambique. It includes the municipalities of Maputo City, Matola City, and Boane City, which is the largest municipality in the country (Barros et al., 2014). Maputo City alone has a population of over 1,191,613 inhabitants as of 2017, spread over an area of 348 km^2, making it the municipality with the highest population density in the country (INE, 2019). This area is home to 8.8% of Mozambique's population, underscoring its importance in the country's socio-economic landscape. The districts of Maputo, Matola, and Marracuene together form Greater Maputo, with a combined population of 2.0 to 2.5 million. Among these districts, Marracuene and Maputo City are the most densely populated areas, while the suburban areas lack structure (Chicombo, 2021).

3.2. Methods

The study strategy for this project involved collecting both qualitative and quantitative data, which enabled a comprehensive investigation of the research questions and objectives. This study utilised two methodologies: content analysis, in which significant topics were examined in national legislative documents, and an online survey conducted with climate scientists and urban planners from Mozambique. Employing mixed methods allows for a comprehensive exploration of the research problem, enabling a deeper understanding of complex systems and fostering actionable insights (Halcomb, 2019). By integrating qualitative and quantitative approaches, this methodology captures the multifaceted nature of climate risk and urban planning, aligning with a systems thinking perspective. Such an approach highlights key leverage points within the system and supports the development of practical, evidence-based solutions that address real-world challenges and the *OPALS* principles for informing adaptation.

A systems thinking approach also underpins this project by emphasizing the importance of understanding complex systems through their interconnected components, feedback loops, and leverage points for transformative change. In this context, addressing coastal hazards in Maputo requires an acknowledgement of the dynamic interactions between environmental, social, and institutional systems. For this project, key leverage points include enhancing information flows—specifically, improving communication about sea level rise and cyclone risks between scientific experts, urban planners, and policymakers. By embedding accurate, timely, and actionable data into planning policy spaces, the project aims to strengthen decision-making processes and foster adaptive urban development.

This systems perspective not only aligns with the need for holistic solutions but also highlights the critical role of feedback loops in monitoring and iterating interventions, ensuring that policies remain responsive to evolving risks and vulnerabilities. Such an approach emphasizes resilience and sustainability as core principles, with the potential to create long-term, systemic change in the face of escalating coastal hazards.

3.3. Ethical considerations

Prior to commencing the research, obtaining ethical permission was crucial for this project. The University furnished a letter of endorsement, the study proposal, a letter soliciting data collection, and consent forms to all selected institutions. The purpose of this was to elucidate the project, articulate the research objectives, explicate the reasons for approaching individuals, apprise them of their rights as research participants, and address the issues of confidentiality and anonymity to the respondents.

3.4. Content analysis

A thorough examination of both national and local policies using content analysis was conducted. Content analysis helps to organize and extract meaning from collected data and to draw realistic conclusions. This method was chosen based on research by Ahmed et al. (2022), which investigated the alignment between climate adaptation and urban policies in Ghana. This study used content analysis to assess the clarity and implicitness of variables in four policies related to urban development and climate change.

Contemporary policies relevant to the topic were selected. The 2020 Disaster Management and Risk Reduction Law, the Masterplan for Disaster Risk Reduction 2017-2030, the Urban Land Regulation (RSU), and the Regulation of the Spatial Planning Law (LOT) were analysed as primary documents.

3.5. Survey

The study involved two groups - climate scientists and urban planners - to assess knowledge on communicating sea level rise and cyclone risk in Maputo Planning Policy Spaces. Ten institutions were selected for participation based on this identification (see Appendix 1).

The sampling technique used was the snowball, also known as chain or network sampling. In this technique, existing study participants recruited future participants from among their networks. The sampling began with one or more study participants and continued based on referrals from those participants until the desired sample or a saturation point was reached. The chosen institutions received letters requesting approval to conduct the survey and a letter of support from the University of Exeter (see Appendix 2). As the survey could only be completed upon internal institutional permission, the process typically took an average of two or more weeks for each institution.

The online questionnaire was created on the MS-FORMS platform, a free tool offered by Microsoft and ran from July 2024 to late August 2024. It was divided into four sections and consisted of 28 questions. The survey design can be found in Appendix 3. The survey was written in English, the common language among the project supervisors, which facilitated the development. As a native Portuguese speaker, I then translated the survey into Portuguese, as the participants' official language is Portuguese.

The open-ended responses were analysed using coding, which involves allocating themes to data by assigning labels, words, or short phrases directly to the transcripts. In vivo coding utilizes the participants' own words, ensuring that the concepts from the data remain close to the participants' own language.

During the questionnaire, interaction with the participants was limited, but it was possible to see the interest in the topic with feedback emails, which agreed with the importance of the concepts presented in the questionnaire. Generally, there were no doubts about the questions; however, I received a few recommendations for improvements.

3.5. Data Analysis

The data collected was carefully analysed and interpreted to minimise bias from the snowball sampling approach. Although the sampling technique is well-suited for a qualitative study, we also used descriptive statistics to show frequency distributions. Our objective was to create a detailed summary of the survey data to gain a better understanding of the key research questions We conducted exploratory inferential tests including chi-square and ANOVA but the results were not significant enough to be included in the results. To achieve this, free access software tools were used: R (see Appendix 4 for code), and Nvivo 14 for qualitative analysis (thematic analysis).

The use of Free and Open-Source Software (FOSS) tools such as R promotes societal value by enhancing accessibility and equity in research (R Core Team, 2023). By removing financial barriers, these tools allow a diverse range of users—from researchers and policymakers to community organizations—to engage with advanced data analysis and visualization. FOSS tools also foster transparency and reproducibility, as their open nature allows users to review, adapt, and share methodologies freely. This inclusivity not only supports collaborative problem-solving but also ensures that knowledge generated is widely accessible, contributing to more informed and equitable decision-making processes.

4. Results

A hybrid approach is employed in the results and discussion section, integrating quantitative and qualitative data within each thematic section to provide a more comprehensive and cohesive insight. Firstly, the urban and regional planning and management tools in Mozambique were analysed in the content analysis session, followed by the survey descriptive statistics of demographics of urban planners and scientists in Maputo and aspects of the current SLR and cyclone risks communication strategies, including the main challenges, are presented (RQ1 and RQ2), followed by the integration of the scientific information into urban planning and challenges and barriers of adoption. Finally, RQ3 was answered by the themes on critical elements to ensure effective communication and translation of sea level rise and cyclone risk information to urban planning.

4.1. Content Analysis

4.1.1. Urban and regional planning and management tools in Mozambique

Institutional framework

In Mozambique the competencies for urban issues are the responsibility of various state institutions from the ministerial level to local bodies in the municipalities to traditional government (régulos) as described in Table 6:

Table 5. Urban management institutions in Mozambique.

Institution	Competencies	Description
Ministry of State Administration (MAE)	Urban administration	Adviser to the local and authorities on matters of public administration, a coordination with the National Association of Municipalities.
The Ministry of Justice; Ministry of Agriculture	Land and property management	Land registration (with regard to the change or transfer of land use rights) and property titling.
Ministry of Public Works and Housing; The Ministry of the Environment; Ministry of Planning and Development	Planning and Urban Development	Drawing up the National Urban Land and Housing Policy and for control of the quality of public infrastructure; draws up and environmental policy and is also responsible for territorial and urban planning; planning and budgeting at national and local level.
Municipal councils	Urbanisation management	Urbanisation, implementation of housing policy, registration and construction, preparing and approving land use and utilisation plans in coordination with the relevant central institutions.

Urban planning policies

This section reviews Mozambican policies applicable to urban land use, climate change adaptation and climate hazard management from institutional commands to municipal regulations and postures. The focus is on the Local Authorities Law (Law no. 2 of 18 February 1997); the Spatial Planning Law (LOT) and its offshoot Decree 60/2006 of 26 December 2006, the Urban Land Regulation (RSU) that deals in more detail with urban planning and management instruments in Mozambique; the Law 15/2014 for disaster management and the Masterplan for disaster risk reduction 2017-2030, described in Table 7.

Table 6. Urban land use and climate change adaptation policies in Mozambique.

Name of law/ policy	**Law 15/2014 Establishing the Framework for Disaster Management, Including Prevention and Mitigation**
Date	**20 June 2014**
Summary	The law serves as the framework law for disaster prevention, mitigation, and management, emphasizing the importance of strategic readiness and systematic preparedness to prevent the impacts of climate change and reduce vulnerability to disasters. It defines strategic readiness as including the identification of climate change impacts, necessary legislation, and education to mitigate these impacts. Among many of its aspects, it gives legal force to some of the issues related to urban management face to climate hazards: > The prohibition of housing construction in areas vulnerable to disasters and the responsibility of Governments and Local Authorities in defining these areas. > The obligatory development of Operations in all public and private institutions and and citizens in general. > The government's obligation to have a Plan. > The obligation to observe alerts.
Name of law/Policy	**Masterplan for Disaster Risk Reduction 2017-2030**
Date	**2017-2030**
Summary	This Masterplan seeks to respond to the provisions of Law No. 15/2014 of 20 June. The plan focuses on fully incorporating Disaster Risk Reduction into governance plans at all levels. The Strategic Objectives of the PDRRD 2017-2030 are: > Improve Understanding of Disaster Risk at all levels. > Strengthening Governance and Public and Private Participation in Disaster Risk Reduction. > Consolidate Public Investment processes, Planning and Financial Protection against disasters.

	> Strengthen capacities for preparedness, response and Rapid Recovery Capacities, especially at the provincial and district levels. > Defining Risk and Disaster Management guidelines; and Management; and > Establish partnerships and international cooperation.
Name of Law/Policy	**Law 2/1997 The Local Authorities Law**
Date	**18 of February 1997**
Summary	This Law ensures that municipalities have the power to find solutions to urbanisation problems by drawing up urban plans at local level, conferred by means of autonomy over the municipal development plan, land use plans, as well as rules on urbanisation and construction under the terms of the law.
Name of Law/policy	**Law 19/2007 Regulation of the Spatial Planning Law (LOT)**
Date	18 July 2007
Summary	This Law lays the foundations for Mozambique's land-use planning system, defining the legal bases for the use and exploitation of land and correct management of urban land and its components, with a view to materialising a sustainable urban development system in the country. All cities and the national territory as a whole are subject to the Law and Regulation of the Spatial Planning Law, which determines that it is compulsory to draw up spatial planning instruments at the local authority level: - Urban structure plans. - General urbanisation plans. - Partial urbanisation plans. and - Detailed plans.
Name of Law/Policy	**Decree no. 60/2006 Urban Land Regulation (RSU)**
Date	**15 July 2006**

Summary	The aim of the regulation is to establish minimum guidelines for solving one of the most serious problems of disorganised urban settlements in Mozambique. The decree establishes regulations on land management in the urban area at local authority level, laying down its principles, objectives and instruments, as well as guidelines on urban management and planning, including the responsibilities of the public authorities and locally applicable planning instruments, subject to the observance of this decree by municipal towns and villages, which presents definitions, classifies urbanisation, presents the Urban Structure Plan, points out infractions and penalties. The law presents some implicit objectives: - The rational and sustainable use of natural resources. - The preservation of environmental balance. - The promotion of citizens' quality of life. - The balance between the quality of life in rural and urban areas. - The improvement of housing conditions, infrastructure and urban systems. - The safety of populations vulnerable to natural or provoked disasters. This regulation considers that disasters are one of the causes for the amendment, revision and suspension of spatial planning instruments that need to be altered for the safety of the population. populations. Similarly, the occurrence or possibility of natural disasters or calamities are causes for the Public Administration to proceed with expropriation for land-use planning purposes. planning.

There are other legal and normative instruments that establish a relationship with urban planning and management, which together have been filling the gap caused by the lack of a more comprehensive urban management policy:

- Decree no. 60/2006, of 26 December, and Ministerial Diploma no. 29-A/2000, of 17 March.
- Law no. 11/97, of 31 May 1997, Law on the Finances and Assets of Local Authorities.
- Decree 45/2004, Regulations on the Environmental Impact Assessment Process.
- Decree no. 11/2006, of 15 June 2006, Regulations on Environmental Inspection.
- Decree no. 13/2006, of 15 June 2006, Regulations on Solid Waste Management.

There are also decrees and policies for urban space management, climate change, climate adaptation and disaster management: the Urban Structure Plan (PEU), the General Urbanisation Plan (PGU), the Detailed Plan (PP) and the Sectoral Master Plan (Solid Waste, Environment, Infrastructure, Roads, Health, etc.); the Municipal Code of Postures, among other legal provisions at municipal level; the National Adaptation Action Plan (NAPA); National Climate Change Mitigation and Adaptation Strategy (ENAMMC); Climate Change and Gender Action Plan (Phase II); Action Plan for the Reduction of Absolute Poverty (PARPA II); Urban Master Plan of Maputo Municipality; Maputo's Resettlement Policy Framework; PROMAPUTO MMDP I, PROMAPUTO MMDP II.

4.2. Survey

4.2.1. Demographics

A total of 31 individuals from 11 institutions took part in the study, with 37.5% working primarily for the local government institutions. Participants from all age categories were represented, with the largest age group being 35-44 (42%), which had 13 participants. The poll revealed a disparate gender distribution, with 16 % females and 84% males. Out of the total, 87% (27) have attained higher education at university level, while 10 % and 3% have completed secondary school (2) and technical vocation, respectively. Finally, regarding professional occupation, 54.8% of the participants are employed as government employees, 16% are engaged in scientific research and 16% work in the private sector.

Table 7. Demographics of our survey respondents.

Demographic Variable	Category	Number of Participants (%)
Gender	Female	5 (16%)
	Male	26 (84%)
Age Group	18-24	2 (6.5%)
	25-34	9 (29%)
	35-44	13 (41.9%)
	45-54	5 (16.1%)
	55 or more	2 (6.5%)
Professional occupation	Government official	17 (54.8%)
	NGO employee	2 (6.5%)
	Private sector employee	5 (16.1%)
	Scientist / Researcher	4 (12.9%)
	Student	3 (9.7%)
Academic Qualifications	Higher education (bachelor's, master's or doctorate)	27 (87%)
	Secondary education	3 (10%)
	Vocational technician	1 (3%)

4.2.2. Sea Level Rise Projections and Cyclone risk perceptions

The participants were surveyed about their perception of the risk of climate disasters. The survey considered their training in sciences and urban planning, their involvement in urban planning and environmental sciences in their work practices, their use of information about climate disasters in their work practices, and whether climate disasters are an important aspect of their work. These aspects may influence their perceptions of future sea level rise projections and views on cyclone risk.

The data reveals that most respondents (45.8%) have formal training or experience in environmental sciences, while 29.2% have expertise in urban planning. A smaller group, 20.8%, reported having formal training or experience in both environmental sciences and urban planning. Only 4.2% of the respondents indicated that they do not have formal training or experience in either field (Figure 12).

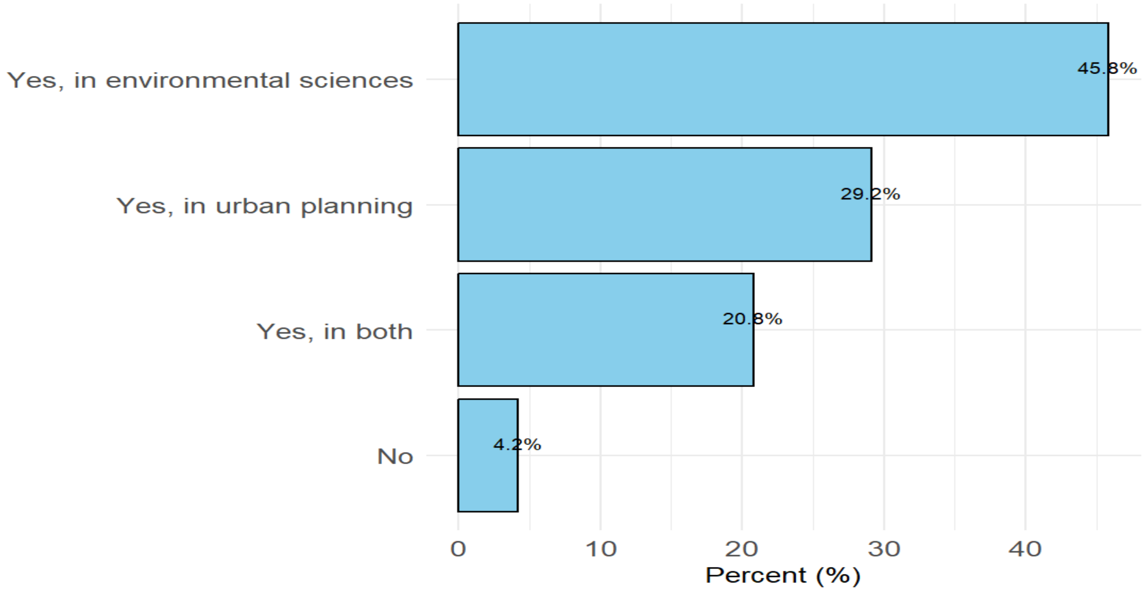

Figure 11. Participants' training in urban planning and environmental sciences showing that the majority has training in both areas.

Approximately 48.4% of respondents reported being involved in urban planning, while 51.6% stated they are not involved in such activities, which could influence how effectively they can integrate scientific information on sea level rise (SLR) and cyclone risks into planning processes. Coastal climate disaster risks play a significant role in the professional lives of most respondents (93.5%), with only 6.5% indicating otherwise.

4.2.3. Communication strategies and main challenges

The first aspect of the current communication strategies analysed was how information on projected SLR and cyclone risks is communicated in the participants' various organizations or institutions. The data reveals that several communication methods are used, with most respondents selecting more than one mode of communication.

Official reports and publications alone emerge as the most common communication channel, with 37.5% of respondents indicating its use. There are complex combinations of communication methods, with some institutions using up to three different channels, such as official reports, email updates, and presentations, as shown in Figure 13.

Figure 12. Main forms of how SLR and cyclone risk information is communicated where combinations of various forms are shown.

The clarity of the information provided on SLR projections and cyclone risks from these sources reveals varying degrees of clarity as perceived by respondents. Specifically, 25% of respondents found the information "very clear," while 29.2% rated it as "moderately clear." Meanwhile, 25% found the information "somewhat clear," and smaller proportions of respondents indicated that the information was "not clear at all" (20.8%) (Figure 14).

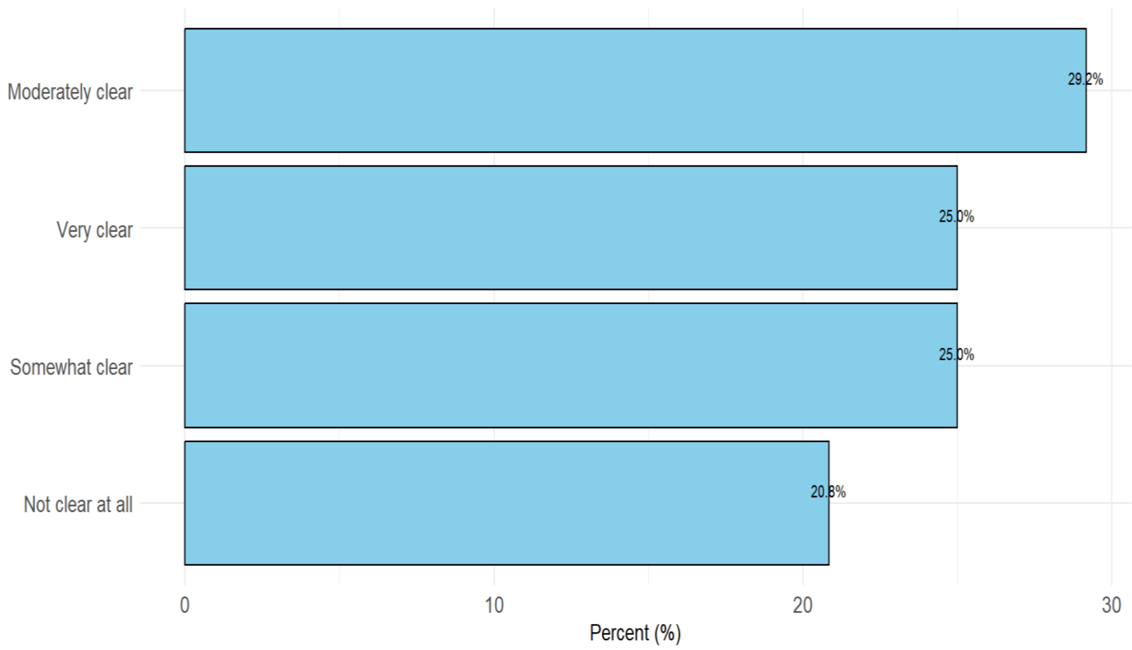

Figure 13. The chart illustrates the variation in the clarity of information regarding sea-level rise (SLR) projections and cyclone risk.

Responses on the perception of projected sea level rise (SLR) and cyclone risks over the next 50 years reveal a diverse awareness level among respondents. Approximately 29% of the respondents perceive these risks, while 9.7% rate their perception as very high. A significant portion, 41.9%, perceive the risks at a moderate level. However, the same percentage (9.7%) perceives the risks as either low or very low.

Regarding communication to other audiences, the data reveal a diverse range of practices and levels of engagement with the following breakdown:

- **Yes** (32.3%): 32.3% of responses indicated that participants' institutions do communicate information about SLR and cyclone risks.

- **No** (32.3%): Similarly, 32.3% of respondents reported that their organizations do not communicate this type of information. This reflects a notable gap where key data on coastal hazards might not reach crucial stakeholders or influence policy and planning as effectively as needed.

- Varied and Specific Forms of Communication (3.2% each): Several respondents (each representing 3.2% of the total) provided specific insights into how their organizations handle the communication of SLR and cyclone information:

P3: "*Yes, mainly coastal communities and Community Fishing Councils, which are the external group we interact with the most"*

P9: *"Normally, my organisation is a consumer of information from other organisations, but as we are producers of information, we also provide this information to other sectors"*

However, when it comes to reliance on other institutions for the same information, findings reveal that 45.16% rely extensively on other institutions as a primary source of technical expertise, information and guidance, while 22.58% only occasionally for specific projects. And the main institutions from which the participants receive information about climate disasters in Mozambique are INAM, INGD, UN-HABITAT, and InOM, with the majority of these being government institutions.

Regarding the main challenges in communication of these climate disasters, the most frequently cited challenge is the technical complexity of information (19.4%). Stakeholder resistance or scepticism follows, noted by 12.9%, reflecting a lack of trust in climate projections. Inconsistent updates and communication barriers, each mentioned by 9.7% of respondents, also pose significant obstacles, with mistrust of sources and language difficulties further complicating the effective dissemination of climate information. Several combinations of these challenges were also mentioned, such as technical complexity combined with inconsistent updates, mistrust of information, or language barriers (see Figure 15). The cumulative percentage shows that these challenges collectively impact the overall communication strategies.

Participants also noted several challenges limiting the use of cyclone and sea level rise projections in urban planning, including insufficient funding or resources, a lack of accurate or reliable data, and the technical complexity of scientific models. Additionally, regulatory and policy barriers were mentioned, with many respondents highlighting a combination of these factors. This underscores the significant interplay between financial constraints, technical difficulties, and regulatory obstacles in incorporating climate projections into planning.

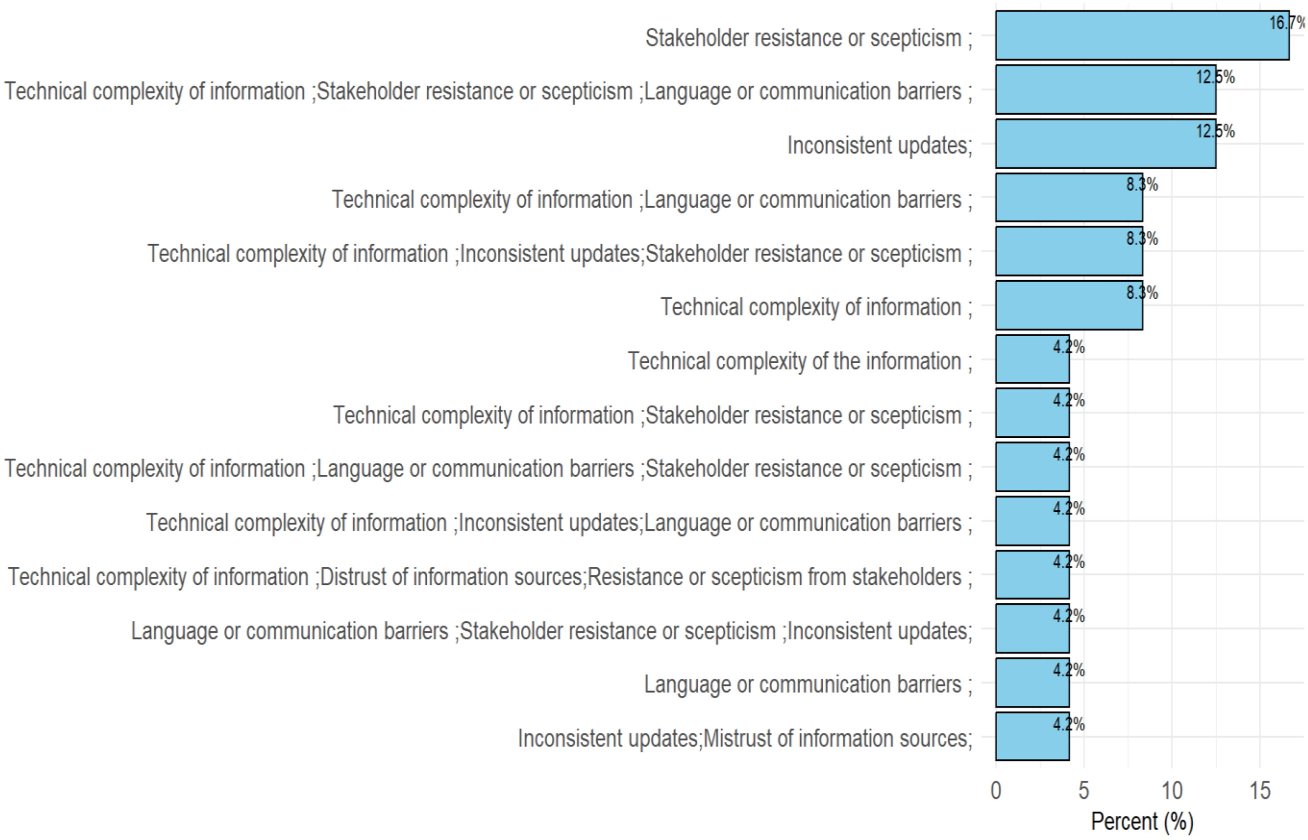

Figure 14. The main challenges in the communication of SLR and cyclone risks identified by respondents, including the main combinations.

Participants were also asked about the integration of climate disaster science into Maputo's urban planning, and 20.8% of respondents felt it was fully integrated and significantly influenced policy, indicating a strong recognition of its importance. In comparison, 25% indicated that it was only partially integrated and occasionally utilised for specific projects, suggesting its consideration is limited but not absent. Meanwhile, 4.2% noted that climate disaster science was not integrated at all, highlighting areas where such data is not utilized (see Figure 16).

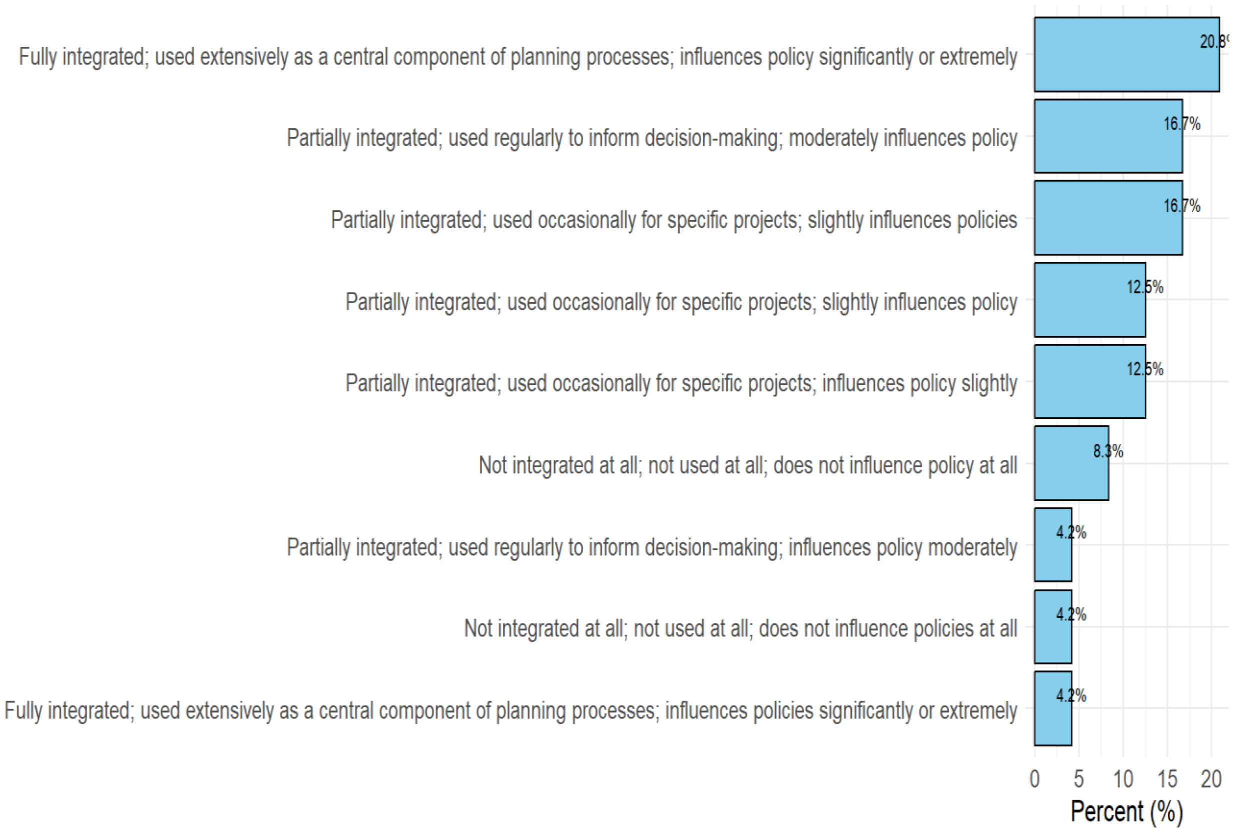

Figure 15. Integration of climate disaster science into current urban planning in Maputo.

4.2.4. Critical elements to ensure effective communication and translation of sea level rise and cyclone risk information

To answer RQ3, open-ended questions were asked to participants, and codes were created from the transcribed responses based on the recurring words or phrases used by the participants.

Figure 16. Word cloud of most repeated words in responses.

The analysis identified key themes, including communication tools, information and evidence quality, communication and dissemination, coordination and support, and information availability and completeness (Table 9).

Table 8. Codes, themes and example quotes from open-ended questions.

Themes	Codes	Examples
Communication Tools	• GPS • Maps • Posters and leaflets • Open access to data • Illustrative images of the SLR evolution • Monitoring	"Historical sea level data up to recent years, images illustrating the evolution of sea level rise, effects of errors caused by sea level rise. Tools: tide gauges, meters for physical and biochemical parameters" "Posters, leaflets, infographics, and social media posts from organisations of this kind would be useful. It's important that the information is easily understood in a quick way and that it also arouses curiosity. Although I don't think communication is exactly the problem we're facing, but rather the application of information in the urban planning process." "'Publications and inspection of planning and implementation of plans". "Lack of implementation once information has been provided "

Information and Evidence Quality	• Accurate information • Comprehensive information • Robustness of information • Increase evidence • Lack of regular updates on available information	"Taking studies and reports more seriously and producing newsletters with accurate information" "Robustness in terms of variation in physical parameters contributing to sea level rise. The area of sea level rise projection is complex, involves statistical and numerical methods, and these are generally drawn up based on the principle of experimentation, calibration and validation of the final product to be presented". "They are reasonably complete but rarely updated regularly. The lack of annually updated data (or depending on the periodicity required) makes urban planning difficult as you can't be planning for the future with outdated data.
Communication and Dissemination	• Local Languages • Information dissemination	"Local community leaders to disseminate information in the local language using local instruments (Batuque, megaphones, community radio)" "Information in local language and use of local channels"
Coordination and Support	• Coordination • Capacity building and training	"Improve intersectoral coordination and communication". "Training programmes at all levels (National, Provincial, District, Local), Ensure Inter-Sector Coordination" "Capacity-building actions, improved production of information and data".
Information Availability and Completeness	• No information available for Maputo • Incomplete information • Not sufficient information available in national reports for integration into urban planning	"We don't have much information available in Maputo" "They are not enough. There is still a challenge in the process of acquiring and making information available in the country." "Of course not, it's clear that there is no information at all, especially regarding the effects on the current context."

5. Discussion

This section examines national urban policies and the primary survey responses. Initially, concentrating on Mozambique's urban laws before delving into current communication strategies and the main obstacles in conveying climate risks to urban planners. Finally, the discussion considered strategies suggested by research participants to address these challenges.

5.1. Mozambique's Urban Management Policies

5.1.2. Urban planning legislation

Mozambique's land-use planning legislation contains important instruments that can enable the country to make the necessary progress in tackling the main urban problems arising from the inappropriate use and occupation of urban land. It is worth highlighting the fact that it provides for the reduction of informal settlements, with the proposal of urban redevelopment through revitalisation or urban requalification. One shortcoming of the legislation is that it does not mention the relevance of drawing up a National Strategic Plan for Urban Management (Leonardo Pontes Teixeira and Souza Pessoa, 2021). Furthermore, the urban management instruments are seen as mere information documents and are ineffective according to each location's reality. They are instruments of land tenure conflicts, which instead of seeking solutions, create problems, often harming a large section of the poor and disadvantaged population who are unaware of land legislation (Muacuveia, 2019).

The country also lacks a National Urban Management Policy that comprehensively addresses the various issues surrounding city management (Macuvaieia, 2019). In this case, there is a need for a conscious attempt to facilitate enforcement and compliance with planning laws and building standards, including basic studies that allow a solid proposal to be drawn up, which should focus on specific aspects, such as urban redevelopment, requalification or revitalisation of degraded areas. The proposal should be the result of a very participatory process for such a complex sector. It is important to consult the main players involved in urban planning and management, namely the municipal authorities and the local authorities (Hurlimann et al., 2021).

Organizations involved in the recovery of informal settlements and reducing their impacts are not recognized in the legislation, despite the significant benefits they can bring to the country, particularly in terms of urban redevelopment (Chicombo, 2021). The current legal framework needs to be organized and improved to overcome its weaknesses, such as confusion, omissions, and ambiguities that make compliance difficult due to the lack of explicit parameters and criteria (Muacuveia, 2019). Although there are some urban management instruments in place, they are limited in scope. Local authorities should implement concrete urbanization and requalification programs by formulating urban public policies that consider the management of urban land occupation in a coordinated and integrated way, with the participation of relevant actors, to promote urban sustainability and prevent informal settlements. Mozambicans may not have extensive knowledge of urban issues, but there is an awareness of the importance of organizing the territory to prevent societal damage.

5.1.3. Current communication strategies

a) Risk Perception versus communication of climate disaster risk

The clarity of information on SLR projections significantly impacts communication strategies and is crucial for effective decision-making and the integration of scientific data into urban planning policies. 35.5% of participants found the information very clear, 29% moderately clear, and 26.2% somewhat clear or not clear at all, indicating room for improvement. The clarity and comprehensibility of climate information are key factors influencing whether it is effectively used in planning and decision-making processes (Moser and Ekstrom, 2010). In the context of Maputo, where urban planners and decision-makers are working to incorporate SLR and cyclone risks into planning frameworks, the lack of clarity in some cases could hinder the effective translation of scientific data into actionable policies (Hirschfeld et al., 2023).

This concern aligns with earlier findings about urban planners' involvement and their perception of risks related to sea level rise (SLR) and cyclones. A significant proportion of respondents (41.9%) perceived these risks as moderate, which may be partly due to the lack of clear and accessible information. When risk-related information is unclear or poorly communicated, it can lead to misunderstandings or underestimations of the threats, ultimately compromising the quality of planning and adaptation strategies (Whitmarsh, 2008).

This issue can be extended to early warning systems, where critical inadequacies in the interpretation of warnings have been identified. For instance, some residents in Beira reportedly understood that a tropical cyclone Idai was expected to make landfall but failed to grasp the implications of its intensity (Engelbrecht and Vogel, 2021). They assumed its impacts would resemble those of weaker tropical storms that frequently affect the area, highlighting a disconnect between warning communication and public understanding. Such gaps in comprehension underscore the need for improved communication strategies to ensure that people not only receive timely warnings but also fully understand the severity of potential impacts (Engelbrecht and Vogel, 2021).

Furthermore, these findings are consistent with broader literature on the communication of climate science, which emphasizes the importance of tailoring information to the needs of different audiences to enhance understanding and uptake. Technical information, when not well-communicated, can be challenging for non-experts to interpret, creating gaps in understanding and potentially resulting in ineffective policy responses (Moss et al., 2010).

Given that nearly half of the respondents are involved in urban planning, the varying clarity of the information they receive suggests that the current communication strategies might not be fully effective in conveying critical SLR and cyclone risk data. Ensuring that information is not only available but also clear and comprehensible is essential for enabling stakeholders to make informed decisions and integrate climate risks effectively into planning processes (Patt and Schroter, 2008).

Language also plays a significant role in communication effectiveness. The preference for Portuguese, indicated by 50% of respondents, is reflective of its status as the official language in Mozambique. However, the inclusion of local languages and English highlights the linguistic diversity of the audience and the need for multilingual communication strategies to ensure inclusivity and reach. The literature supports the notion that multilingual communication can enhance comprehension and engagement, particularly in regions with diverse linguistic backgrounds (Renn and Walker, 2008).

The institutions from which participants receive information, primarily governmental bodies like INAM, INGD, UN-HABITAT, and InOM, are central to the dissemination of disaster risk information in Mozambique(Cabral et al., 2017). However, the reliance on official reports and publications and the limited use of internal chat channels suggests that communication within institutions may be formal and possibly infrequent. This could hinder timely and effective knowledge sharing, as informal communication channels have been shown to be vital in facilitating the quick exchange of information and fostering collaboration (Cross et al., 2001).

The responses about external communication of Sea level rise and cyclone risks show a varied landscape. While some institutions engage directly with external groups such as coastal communities and through conferences, others are more passive consumers of information or limit their communication to specific topics like cyclone risks. This selective communication could be a result of institutional mandates or resource constraints, but it may also indicate a missed opportunity for broader public engagement, which is critical for building community resilience (Chirisa and Matamanda, 2022).

b) Reliance on Other Institutions for Information

Reliance on other institutions for information on sea level rise and cyclone risks is a crucial aspect of disaster management and planning. The frequency with which institutions rely on external sources for guidance and best practices can significantly impact the effectiveness of their strategies. The survey results indicate that 40% of participants rely extensively on other institutions as a primary source of information and guidance, while 29% do so occasionally, primarily for specific projects. This pattern of reliance is reflective of broader trends in disaster management in developing countries, where local institutions may lack the resources or expertise to develop comprehensive disaster risk management strategies independently (Wisner et al., 2004).

Mozambique's reliance on external sources can also be seen in its collaborations with international organizations such as the United Nations Office for Disaster Risk Reduction (UNDRR) and the World Bank, which provide critical guidance on disaster risk reduction practices. For instance, the World Bank's involvement in the Mozambique Integrated Disaster Risk Management and Resilience Program has been instrumental in enhancing local capacities to manage disaster risks, particularly through the provision of technical expertise and financial resources (Word Bank, 2016). However, the over-reliance on external sources can sometimes lead to a lack of localized adaptation of these strategies, making them less effective in the unique contexts of Mozambique.

Moreover, institutions that rely on external guidance only occasionally, primarily for specific projects, may face challenges in maintaining continuity and consistency in their disaster risk management approaches. The sporadic use of best practices can result in fragmented and disjointed strategies that fail to address the comprehensive needs of disaster management. This issue underscores the importance of building internal capacities and fostering institutional knowledge to reduce dependency on external sources and promote sustainable, locally-driven disaster management practices (UNDP, 2017).

c) Challenges and Barriers in Communication

The communication of SLR projections and cyclone risk information in Mozambique faces several significant barriers, which can be broadly categorized into communication challenges and operational and stakeholder issues. Language barriers and the technical complexity of the information are among the most prominent challenges identified by the survey participants.

Language is a critical barrier in Mozambique, a country with multiple local languages alongside Portuguese, the official language. While 50% of participants preferred receiving information in Portuguese, the exclusion of local languages can limit the reach and effectiveness of communication efforts, particularly in rural and coastal communities where local languages are predominantly spoken (Nerlich et al., 2010). The literature suggests that multilingual communication strategies are essential in ensuring that disaster risk information is accessible to all segments of the population, thereby enhancing community preparedness and resilience (Zschau and Kïppers, 2013).

The technical complexity of SLR and cyclone risk information is another significant barrier. The use of complex scientific data and models can be challenging for non-experts and urban planners to understand, leading to misinterpretation or disengagement from the information. This complexity is particularly problematic in contexts where technical literacy is low, as is often the case in many developing countries (Lemos and Rood, 2010). In Mozambique, efforts to simplify and translate technical information into more accessible formats are necessary to ensure that all stakeholders can effectively engage with and act on the information (Chirisa and Matamanda, 2022).

Operational and stakeholder issues, such as inconsistent updates and resistance or scepticism from stakeholders, further complicate communication efforts. Inconsistent updates can lead to confusion and erode trust in the information being provided, while resistance from stakeholders can stem from a variety of factors, including a lack of understanding, fear of economic impacts, or political considerations (Slovic, 1999). Addressing these barriers requires a concerted effort to build trust through transparent and consistent communication, as well as engaging stakeholders in the communication process to ensure that their concerns are addressed (Covello and Sandman, 2001).

Challenges in Integration of SLR and Cyclone Risk Information into Urban Planning

The findings also point to significant challenges in integrating SLR and cyclone risk information into urban planning. The majority indicated that the integration is either partial or minimal, stating that the information is occasionally used and has a slight influence on policies. This limited integration could be attributed to several factors, including the complexity of technical data, insufficient resources, and existing regulations that may not support the incorporation of new scientific insights.

The identification of technical data complexity as a major barrier aligns with broader concerns about the accessibility and usability of climate data in decision-making. As highlighted in the literature, the complexity of climate models and projections can be a significant obstacle to their application in policy and planning, especially when decision-makers lack the necessary expertise or resources to interpret and utilize this information effectively (Lemos and Rood, 2010). The ability to create complicated models has exceeded the understanding of their feedback and uncertainties. This can lead to a lack of trust in the modelling process and results by decision-makers (Chu and Schenk, 2017).

Additionally, the lack of detailed data and insufficient funding/resources are critical barriers to effectively integrating climate risk information into urban planning. These challenges echo findings from other studies emphasizing the need for increased investment in data collection, capacity building, and supportive regulatory frameworks (Moser and Ekstrom, 2010). Sustainable funding for urban planning practices is particularly critical (Hurlimann et al., 2021). Addressing these barriers requires innovative solutions, such as creating opportunities for private sector participation in socioeconomic infrastructure development and securing long-term funding for ambitious yet appropriate adaptation projects in developing countries.

Such efforts align with commitments under the Paris Agreement, which stresses the importance of funding climate adaptation alongside mitigation. Developing countries must prioritize the construction of inclusive and detailed Nationally Determined Contributions (NDCs) on adaptation, including accurate cost estimates. These contributions serve as essential foundations for future negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). Realizing the climate funding pledges made in the Copenhagen Accord and subsequent agreements is crucial to addressing vulnerabilities (Engelbrecht and Vogel, 2021).

This underscores the urgent need for equitable funding mechanisms that not only help developing countries implement resilient infrastructure projects but also address systemic challenges, ultimately reducing their exposure to climate risks (Engelbrecht and Vogel, 2021).

5.1.4. Critical elements to ensure effective communication and translation of sea level rise and cyclone risk information in urban planning

Communication Tools

The theme of Communication Tools encompasses the use of various instruments, including geospatial data and mapping, data collection and observation tools, and visual communication tools for conveying scientific information to decision-makers and the public. The increasing availability of geospatial data through tools such as Geographic Information Systems (GIS) has revolutionized urban planning by allowing for spatial analysis of climate impacts (Goodchild, 2010). Specifically, the use of real-time data collection methods such as tide gauges and remote sensing technologies enables planners to monitor environmental changes, such as sea level, in near real-time (Cutter, 2016).

However, the effectiveness of these tools often hinges on the capacity to interpret and integrate data into actionable policies (Lipscomb et al., 2024). As highlighted by some respondents, while data collection is not the primary problem, the challenge lies in the application of this information within urban planning processes. Data availability often exceeds its utilization in policymaking, primarily due to institutional and technical barriers (Nehama et al., 2022). For example, while planners may have access to visual tools such as infographics and maps, there is a tendency for these to remain siloed in technical departments without being adequately translated into practical urban development strategies (MacEachren and JKraak, 2001). The use of tools such as maps may also have unintended consequences, as shown in a study by Mildenberger *et al.*, (2024) that revealed that map-based risk information increases support for collective spending on climate adaptation but does not increase individual intentions to contribute. Additionally, it may reduce concern about future sea-level rise, even among households projected to experience flooding this century.

Moreover, the dissemination of complex data must be simplified for broader public consumption. The use of infographics, posters, and social media provides an accessible way to communicate risk to a wider audience (Welch and Jackson, 2007); however, it is important to empirically test messaging campaigns for climate adaptation (Mildenberger et al., 2024). As suggested by interviewees, simply providing data is not sufficient—what is needed is the integration of this information into decision-making processes. The lack of implementation after information is shared highlights a critical disconnect between knowledge production and action. This gap arises as information dissemination often fails to lead to meaningful outcomes, hindered by institutional inertia and poor coordination (Moser and Ekstrom, 2010).

Information and Evidence Quality

The quality of information and evidence is another critical theme in this analysis. Climate adaptation efforts require accurate, comprehensive, and up-to-date information, yet many urban planners still rely on outdated or incomplete datasets (Requier et al., 2020). The robustness of data, including the level of detail in physical parameters such as sea level rise and storm surge projections, is crucial for making informed decisions (Nicholls and Cazenave, 2010). However, participants note that the lack of regular updates on available information limits their ability to plan for future risks effectively. Outdated data reduces the accuracy of risk assessments and compromises the resilience of urban planning (Hallegatte et al., 2013).

The importance of evidence-based planning is widely acknowledged in climate adaptation literature. For instance, scientific robustness involves not only collecting accurate data but also ensuring that projections and models are validated through calibration and experimentation, as highlighted in the participants' responses. This process, which is a standard in climate modelling (IPCC, 2014), requires continuous monitoring and the refinement of models to account for emerging trends and anomalies, such as unexpected climate shifts or rapid urbanization (Rosenzweig et al., 2018).

As noted by participants, a recurring challenge is that national reports and datasets often fail to reflect local conditions, making it difficult to apply them directly to urban planning in cities like Maputo. This disconnect between national-level data and local application is a significant barrier, as local conditions, such as topography and specific vulnerabilities, need to be considered for accurate urban planning (Bull-Kamanga et al., 2003). Cities require localized, granular data that can be used to inform infrastructure development and disaster preparedness, which is often lacking in national climate reports (Revi et al., 2014).

Communication and Dissemination

The theme of communication and dissemination emphasizes the need for effective communication strategies that resonate with local communities. While technical data and reports are essential for policymakers, local communities—who are often the most vulnerable to climate impacts—require information that is accessible and actionable. One effective strategy identified in both the literature and the respondents' examples is the use of local languages and culturally appropriate communication methods, such as community radio, megaphones, and traditional gatherings (Crate and Nuttall, 2016). These methods ensure that even populations with low literacy levels or limited access to formal education can understand the risks they face and how to mitigate them.

The use of community leaders as conduits for disseminating climate information aligns with findings from previous research, which shows that local trust networks are vital for effective communication, particularly in regions with limited formal governance structures (Armitage et al., 2011). In cases where governments or NGOs attempt to disseminate information without the involvement of local leaders, the message is often lost or mistrusted (Mercer, 2010).

Moreover, the need for simplified, locally relevant communication is consistent with disaster risk reduction (DRR) literature, which emphasizes the importance of engaging communities in co-produced knowledge (Prabhakar et al., 2009). This process involves working with local stakeholders to ensure that scientific knowledge is not only disseminated but also contextualized in a way that reflects local values, knowledge systems, and decision-making structures (Weeks et al., 2024). The use of local languages and traditional instruments—as mentioned in the examples—further supports this, ensuring that information is effectively translated into local contexts (Mercer, 2010).

Coordination and Support

Coordination and support between different governmental levels and sectors is a recurring theme in the data and literature. As noted by the respondents, improving intersectoral coordination is key to ensuring that scientific information is effectively integrated into urban planning (Bulkeley and Betsill, 2013). Effective climate adaptation requires collaboration between various sectors, such as urban planning, environmental management, and disaster risk reduction (Leck and Simon, 2013). However, the lack of such coordination often leads to fragmented policies that fail to address the interconnectedness of climate risks.

Research on urban climate governance suggests that one of the most significant barriers to adaptation is the absence of a coherent, multi-level governance structure that aligns national, regional, and local actions (Anguelovski and Carmin, 2011). The respondents' call for capacity-building programs at all administrative levels is crucial, as local governments often lack the technical expertise and financial resources needed to implement climate policies effectively (Carmin et al., 2013) . Such programs should focus on training urban planners and local authorities to use scientific data in their decision-making processes, thereby enhancing the adaptive capacity of cities like Maputo.

Additionally, the literature highlights that improving coordination between sectors can help in pooling resources and expertise, enabling a more holistic approach to urban resilience (Dodman and Satterthwaite, 2009). For example, integrating climate science into urban planning not only involves data from environmental agencies but also requires inputs from infrastructure, health, and social services sectors to ensure that the city can withstand and recover from climate shocks (Pelling et al., 2018).

Information Availability and Completeness

A significant challenge identified in the data is the lack of available and comprehensive information, particularly in cities like Maputo. Participants highlighted that much of the data necessary for effective urban planning is incomplete or unavailable, hindering accurate risk assessments and adaptation strategies (Satterthwaite, 2007). Data gaps are a common barrier to climate resilience, especially in low-income countries where infrastructure for climate data collection is inadequate (Henriques and Correia, 2023).

The absence of localized information complicates the identification of specific vulnerabilities within cities. Without sufficient data on urban infrastructure, population dynamics, and local climate patterns, planners struggle to manage climate risks effectively (Sterzel et al., 2020). Respondents also noted the lack of national reports providing actionable insights for urban planners, echoing broader critiques of the disconnect between national climate assessments and local planning needs (Revi et al., 2014).

This issue is further exacerbated by limited institutional capacity in many Global South cities, including Maputo, to generate and maintain high-quality datasets (Anguelovski and Carmin, 2011). Urban planners often depend on outdated or incomplete data, complicating efforts to plan for future climate scenarios. Fast-growing urban areas face additional challenges as rapid urbanization amplifies vulnerabilities to impacts like flooding and sea-level rise (Dodman and Mitlin, 2013).

Urban Planning and Integration

Urban planners require accurate, scientifically robust data to identify risk zones and develop adaptation strategies (Rosenzweig et al., 2018). However, as participants noted, the integration of this data into planning processes is often limited due to institutional barriers and a lack of technical capacity. The integration of climate data into planning is a key determinant of a city's ability to adapt to climate change (Tyler and Moench, 2012).

One of the main barriers to integration is the fragmentation of urban planning processes, where climate data is often treated as a separate issue rather than being incorporated into broader urban development strategies (Aylett, 2015). In cities like Maputo, where rapid urbanization is occurring alongside increasing climate risks, the failure to integrate climate data into planning processes can exacerbate vulnerabilities (Pelling et al., 2018). Urban planners need to consider both current climate impacts and future projections to develop resilient infrastructure and protect vulnerable communities (Dodman et al., 2012).

Moreover, the literature emphasizes that successful integration of climate data into urban planning requires not only technical capacity but also institutional support. Cities that are successfully adapting to climate change often rely on strong institutional frameworks that promote the use of scientific data in decision-making processes (Bulkeley and Betsill, 2013). This requires political will and a commitment to long-term planning, as well as the development of cross-sectoral governance structures that can coordinate adaptation efforts across different policy areas (Dodman et al., 2012).

6. Conclusions

This dissertation investigated the current communication mechanisms for conveying sea level rise (SLR) projections and cyclone risks to urban planning policies in Maputo. Significant challenges were identified, including limited access to reliable data, the technical complexity of the information, and language barriers, all of which hinder engagement with a diverse audience. Institutional constraints, such as bureaucratic inefficiencies and a lack of coordination among government agencies, further exacerbate these issues. While laws exist to address these challenges, their implementation remains minimal, highlighting the need for enhanced data quality, improved communication tools, better inter-agency coordination, and more comprehensive dissemination efforts. These steps are essential to improve risk communication, strengthen stakeholder engagement, and integrate critical information into urban planning policies.

Current adaptation strategies in Maputo also fall short of addressing the city's inherent complexities and interdependencies. As a complex system, Maputo's social, economic, and environmental components are deeply interconnected, yet many adaptation efforts fail to account for these interactions. For instance, infrastructure-focused solutions like seawall construction often overlook potential disruptions to local communities or ecosystems. Additionally, siloed approaches, which address specific issues such as flood control or coastal erosion in isolation, neglect the broader impacts on areas like housing, transportation, and public health. Future research should explore integrated, cross-sectoral strategies that adopt a systems-thinking perspective, considering how various components of the urban environment interact. By promoting holistic urban resilience, such strategies could better address the vulnerabilities of Maputo and other cities like Beira, Quelimane, and Inhambane, which face similarly high risks from climate disasters. These areas require urgent attention and focused research to address their concerning future projections.

7. References

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8. Appendix

Appendix 1. List of Institutions contacted.

Institution Name	Participation Status
INAHINA - National Institute for Hydrography and Navigation	NO
INAM - National Institute of Meteorology	YES
INGD- Mozambique National Institute of Disaster Management	YES
InOM - Institute of Oceanography of Mozambique	YES
LEM - Mozambique Engineering Laboratory	NO
ESCMC - School of Marine and Coastal Sciences	YES
MOPHRH - Ministry of Public Works, Housing and Water Resources	NO
MTA - Ministry of Land and Environment	YES
Maputo Municipal Council	NO
UEM - Eduardo Mondlane University	YES
UN- Habitat	NO
Others (mainly private institutions)	YES

Appendix 2. Authorization letters.

21492579
Faustina

r, Reino Unido

da Julião Cossa, matriculada no programa de Mestrado em *Global Sustainability Solutions* da
está atualmente desenvolvendo uma pesquisa intitulada **Informando a Adaptação aos Riscos**
do nível do mar e do risco de ciclones nas áreas urbanas de Maputo sob minha orientação.
estratégias de comunicação científica ligam as previsões da subida do nível do mar e dos
z parte dos requisitos para a conclusão do curso de mestrado. A metodolog ia da pesquisa
m os principais intervenientes no planeamento urbano da Província de Maputo e também
mação, para coletar dados relevantes que contribuirão para um melhor entendimento do

sa e assegura que todas as diretrizes éticas e de confidencialidade será o rigorosamente
tas de maneira profissional e a respeitar todas as normas e regulamentos da instituição

a seu conhecimento e avaliação. Estamos à disposição para fornecer qualquer

pesquisa da nossa estudante.

ssertação da Minda Julião Cossa

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02.07.24

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Amory Building, Streatham Campus, Exeter, Reino Unido
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Website: https://www.exeter.ac.uk/
Data: 05.06.2024

Ref:

Prezados

Venho por meio desta apresentar a estudante Minda Julião Cossa, matriculada no programa de Mestrado em *Global Sustainability Solutions* da Universidade de Exeter, Reino Unido. A estudante está atualmente desenvolvendo uma pesquisa intitulada **Informando a Adaptação aos Riscos Costeiros: Reforço da Comunicação sobre a subida do nível do mar e do risco de ciclones nas áreas urbanas de Maputo** sob minha orientação.
A pesquisa visa avaliar a eficácia com que as atuais estratégias de comunicação científica ligam as previsões da subida do nível do mar e dos ciclones às políticas de planeamento em Maputo, e faz parte dos requisitos para a conclusão do curso de mestrado. A metodolog ia da pesquisa inclui a realização de entrevistas e inquéritos online com os principais intervenientes no planeamento urbano da Província de Maputo e também os investigadores que trabalham na produção da informação, para coletar dados relevantes que contribuirão para um melhor entendimento do tema estudado.
A Universidade de Exeter apoia plenamente esta pesquisa e assegura que todas as diretrizes éticas e de confidencialidade serão rigorosamente seguidas. A estudante foi instruída a conduzir as entrevistas de maneira profissional e a respeitar todas as normas e regulamentos da instituição que gentilmente conceder a autorização.
Anexamos a esta carta o plano de pesquisa detalhado para seu conhecimento e avaliação. Estamos à disposição para fornecer qualquer informação adicional que seja necessária.

Agradecemos antecipadamente pela colaboração e apoio à pesquisa da nossa estudante.

Atenciosamente,

Dr. Ricardo Safra de Campos
Senior Lecturer do Departmento de Geografia e orientador da dissertação da Minda Julião Cossa
University of Exeter

INSTITUTO NACIONAL DE METEOROLOGIA
SECRETARIA GERAL
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University of Exeter

CONSELHO MUNICIPAL
Secretaria Geral
Entrada n.º.........
Data 02 / 07 / 024

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Appendix 3. Translated questionnaire.

Parte 1. Informações gerais sobre os participantes

1. Qual é a sua faixa etária?

   - [ ] 18-24
   - [ ] 25-34
   - [ ] 35-44
   - [ ] 45-54
   - [ ] 55 ou mais

2. Qual e o seu género?

   - Masculino
   - Feminino
   - Não-binário
   - Prefere não dizer

3. Quais são as suas qualificações académicas?

   - [ ] Nenhuma educação formal
   - [ ] Ensino primario
   - [ ] Ensino secundário
   - [ ] Ensino superior (licenciatura, mestrado ou doutoramento)
   - [ ] Outro (por favor especifique)

4. Tem alguma formação ou experiência formal em ciências do ambiente ou planeamento urbano?

   - [ ] Sim, em ciências ambientais
   - [ ] Sim, em planeamento urbano
   - [ ] Sim, em ambos
   - [ ] Não

5. Qual é a sua ocupação profissional?

   - [ ] Funcionário público
   - [ ] Cientista / Investigador
   - [ ] Funcionário de ONG
   - [ ] Empregado do sector privado
   - [ ] Outro (Por favor, especifique).

6. Qual é o nome da sua organização? (A sua resposta será mantida anónima no relatório publicado. Por exemplo, em vez de utilizar nomes específicos, as respostas serão referidas em termos gerais, como "um funcionário de um departamento de planeamento municipal"). (Opcional).
7. Está envolvido no planeamento urbano operacional (por exemplo, planeamento urbano, desenvolvimento de infra-estruturas e/ou planeamento da utilização dos solos, resiliência urbana, desenvolvimento urbano, planeamento urbano ou política ambiental)?

   - [ ] Sim / [ ] Não

8. Quais são as suas funções? Especifique o seu cargo (por exemplo, urbanista, cientista ambiental, analista de políticas) e descreva sucintamente as suas principais responsabilidades.
9. Os riscos de desastres climáticos costeiros desempenham um papel significativo nas suas práticas de trabalho?
10. Utiliza informação sobre perigos e riscos climáticos costeiros na sua prática profissional? (Escala de 1 a 5, em que 1 = muito pouco e 5 = muito)

    - [ ] 1 (Muito pouco)
    - [ ] 2
    - [ ] 3
    - [ ] 4
    - [ ] 5 (Muito)

11. Há quanto tempo trabalha/vive em Maputo?

- [ ] Menos de 1 ano
- [ ] 1-3 anos
- [ ] 4-6 anos

- [ ] 7-10 anos

- [ ] Mais de 10 anos

13. Em que língua(s) se sente mais à vontade para receber informações? (Seleccione todas as alternativas que se aplicam)

    - [ ] Português

    - [ ] Inglês

    - [ ] Línguas locais (por exemplo, Changana ou Ronga)

    - [ ] Outra (por favor especifique)

Parte 2. Estratégias de comunicação

14. Como classificaria o seu nível de perceção da projeções evolução da subida do nível do mar e dos riscos de ciclones nos próximos 50 anos?

    - [ ] Muito baixo

    - [ ] Baixo

    - [ ] Moderado

    - [ ] Alto

    - [ ] Muito Elevado

15. Liste todas as organizações de onde obtém informações sobre a subida do nível do mar e riscos de ciclones.

16. Como é atualmente comunicada na sua organização a informação sobre as projeções de subida do nível do mar e os riscos de ciclones? (Selecione todas as alternativas que se aplicam)

    - Através de relatórios e publicações oficiais

    - Através de actualizações por correio eletrónico ou boletins informativos

    - Através de apresentações ou reuniões

- Através de canais de conversação internos (por exemplo, MS Teams, Slack, WhatsApp)

- [ ] Outros (especificar): _______

16. A sua organização/ instituição comunica informações sobre projeções da subida do nível do mar e os riscos de ciclones a audiências externas?

17. Em que medida é que a sua organização/instituição depende de informações/orientações de outras instituições sobre projeções da subida do nível do mar e os riscos de ciclones?

- De modo algum

- Ocasionalmente, para projectos específicos

- Moderadamente, para orientação geral e melhores práticas

- Extensivamente, como fonte primária de conhecimentos técnicos, informação e orientação

- [ ] Outra (especificar): _______

18. Como classificaria a clareza da informação fornecida sobre projeções de subida do nível do mar e riscos de ciclones em Maputo?

[ ] Não é claro de todo

[ ] Um pouco clara

[ ] Moderadamente clara

[ ] Muito clara

[ ] Extremamente clara

19. Que principais desafios pode identificar na comunicação das projeções da subida do nível do mar e riscos de ciclones? (Selecione todas alternativas que se apliquem)

- Complexidade técnica da informação

- Actualizações incoerentes

- Desconfiança nas fontes de informação

- Resistência ou ceticismo das partes interessadas

- Barreiras linguísticas ou de comunicação

- Outros (especificar): _______

20. Que papel desempenha uma comunicação eficaz na coordenação dos esforços de planeamento para mitigar os impactos da subida do nível do mar e das tempestades em Maputo?

- Essencial para a construção de apoio e envolvimento público

- Facilita a colaboração e coordenação entre as partes interessadas

- Ajuda a garantir a tomada de decisões informadas pelos decisores políticos

- Aumenta a transparência e a responsabilidade nos processos de planeamento

- [ ] Outro (por favor especifique): _______

Parte 3. Integração da subida do nível do mar e dos ciclones no planeamento urbano

21. Até que ponto acha que a ciência dos desastres climáticos, incluindo as mudanças projectadas nos ciclones e na subida do nível do mar, está integrada nas actuais políticas de planeamento urbano em Maputo, e até que ponto esta informação influencia a tomada de decisões?

- Totalmente integrada; utilizada extensivamente como uma componente central dos processos de planeamento; influencia as políticas de forma significativa ou extrema

- Parcialmente integrada; usada regularmente para informar a tomada de decisões; influencia as políticas moderadamente

- Parcialmente integrada; utilizada ocasionalmente para projectos específicos; influencia ligeiramente as políticas

- Não integrado de todo; não é utilizado de todo; não influencia as políticas de todo

- Não tem a certeza

- Outro (especificar): _______

22. Que desafios considera que limitam a utilização das projecções de ciclones e da subida do nível do mar no planeamento urbano? (Seleccione todos os que se aplicam)

- Complexidade técnica - Os dados e modelos científicos são demasiado complexos para serem facilmente compreendidos e aplicados pelos planeadores urbanos.

- Financiamento/recursos insuficientes para actividades de planeamento urbano

- Falta de dados exactos ou pormenorizados - dados insuficientes ou pouco fiáveis sobre a subida do nível do mar e ciclones)

- Barreiras regulamentares e políticas: Os regulamentos e políticas existentes não são conducentes à integração de novas informações científicas.

- Outros (especificar): _______

23. Que informação ou recursos adicionais o ajudariam a integrar melhor a informação sobre a subida do nível do mar e ciclones no planeamento urbano de Maputo? (Selecione todas as alternativas que se apliquem)

- Melhoria da qualidade e exatidão dos dados

- Acesso a formação especializada ou programas de capacitação

- Apoio financeiro para projectos de adaptação

- Oportunidades de colaboração com outras instituições ou especialistas

- Melhoria da comunicação e dos esforços de divulgação

- [ ] Outros (especificar): _______

24. Até que ponto está satisfeito com as actuais estratégias de comunicação utilizadas para transmitir informações sobre a subida do nível do mar e ciclones em Maputo?

- Muito insatisfeito

- [ ] Um pouco insatisfeito

- Neutro

- Um pouco satisfeito

- Muito satisfeito

- [ ] Outro (especificar): _______

Entrevista semi-estruturada

1. Abrangência:

a. Considera que as informações sobre a subida do nível do mar e os ciclones fornecidas nos relatórios nacionais são suficientemente completas e pormenorizadas para serem utilizadas no planeamento urbano?

b. Qual a importância de outras fontes de informação (por exemplo, relatórios científicos, estudos ou boletins) para as necessidades de planeamento urbano, e porquê?

2. Clareza e acessibilidade:

Que informações, recursos adicionais, ferramentas específicas, visuais ou tipos de dados seriam particularmente úteis para integrar melhor a os dados ou orientações cientificas de projeções da subida do nível do mar e risco de ciclones no planeamento urbano em Maputo?

3. Sugestões de melhoria:

a. Que melhorias pensa que poderiam aumentar a eficácia das estratégias de comunicação relativas à subida do nível do mar e ciclones em Maputo?

Appendix 4. R packages and codes.

1. Packages:

```
library(tidyverse)

library("scales")
```

2. Descriptive statistics (code applied for questions except the open-ended).

```
#Import data

    survey_ <- read_csv("Data/DataforR.csv")
```

```
#Academic qualifications

head(survey)

glimpse(survey)

pl1<- ggplot(data = survey_)

pl1<- pl1 + geom_bar(aes(x = `Academic qualifications`))

pl1<- pl1 + theme_minimal()

pl1

pl1<- ggplot(data = survey_)

pl1<- pl1 + geom_bar(aes(x = `Academic qualifications`, y = after_stat(count/sum(count))))

pl1<- pl1 + theme_classic()

pl1<- pl1 + scale_y_continuous(labels = percent)

pl1

Qualificationscount<- survey_%>%

  dplyr::count(`Academic qualifications`)%>%

  dplyr::mutate(perc = n/sum(n)*100)

pl1<- ggplot(data = Qualificationscount, aes(x = `Academic qualifications`, y = n))

pl1<- pl1 + geom_col()

pl1<- pl1 + geom_text(aes(x = `Academic qualifications`, y = n

                         , label = paste0(n, "(",round(perc, 1),"%)")

                         ,vjust = - 0.5))
```

```
pl1<- pl1 + theme_classic()

pl1<- pl1 + labs (title = "")

pl1

# Involvement in urban planning

pl1<- ggplot(data = survey_)

pl1<- pl1 + geom_bar(aes(x = `Involvement in urban planning`))

pl1<- pl1 + theme_minimal()

pl1

pl1<- ggplot(data = survey_)

pl1<- pl1 + geom_bar(aes(x = `Involvement in urban planning`, y = after_stat(count/sum(count))))

pl1<- pl1 + theme_classic()

pl1<- pl1 + scale_y_continuous(labels = percent)

pl1

Involvementcount<- survey_%>%

  dplyr::count(`Involvement in urban planning`)%>%

  dplyr::mutate(perc = n/sum(n)*100)

pl1<- ggplot(data = Involvementcount, aes(x = `Involvement in urban planning`, y = n))

pl1<- pl1 + geom_col()

pl1<- pl1 + geom_text(aes(x = `Involvement in urban planning`, y = n

                          , label = paste0(n, "(",round(perc, 1),"%)")
```

```
                     ,vjust = - 0.5))

pl1<- pl1 + theme_classic()

pl1<- pl1 + labs (title = " ")

pl1
```

3. Example of chi-square and anova results with no statistical significancy.

```
> print(chi_square_test)

        Pearson's Chi-squared test

data:  contingency_table

X-squared = 1.4609, df = 4, p-value = 0.8335
>
```

```
> # summary of the ANOVA test

> summary(anova_result)

            Df Sum Sq Mean Sq F value Pr(>F)

Perceptionof  4  12.93   3.233   2.663 0.0643 .

Residuals    19  23.07   1.214

---

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

> # Tukey's HSD post-hoc to test if ANOVA is significant
```

```
> tukey_result <- TukeyHSD(anova_result)
>
> # Display the Tukey HSD result
> print(tukey_result)
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = Use ~ Perceptionof, data = survey_data)

$Perceptionof
                          diff       lwr        upr     p adj
Low-High           -1.16666667 -3.509620  1.1762872 0.5763024
Moderate-High      -1.10000000 -2.811052  0.6110516 0.3344402
Very High-High     -1.00000000 -3.705410  1.7054100 0.7985224
Very Low-High      -2.50000000 -4.842954 -0.1570462 0.0331095
Moderate-Low        0.06666667 -2.114505  2.2478380 0.9999822
Very High-Low       0.16666667 -2.858074  3.1914071 0.9998141
Very Low-Low       -1.33333333 -4.038743  1.3720767 0.5855555
Very High-Moderate  0.10000000 -2.466577  2.6665773 0.9999532
Very Low-Moderate  -1.40000000 -3.581171  0.7811713 0.3359204
Very Low-Very High -1.50000000 -4.524740  1.5247404 0.5799909
```

Appendix 5. Respondent characteristics

Respondent Age Groups

Age groups	Frequency	Percent	Valid Percent	Cumulative Percent
18-24	2	6.5	6.5	6.5
25-34	9	29.0	29.0	35.5
35-44	13	41.9	41.9	77.4
45-54	5	16.1	16.1	93.5
55 or more	2	6.5	6.5	100.0
Total	31	100.0	100.0	

Respondents Gender

Gender groups	Frequency	Percent	Valid Percent	Cumulative Percent
Female	5	16.1	16.1	16.1
Male	26	83.9	83.9	100.0
Total	31	100.0	100.0	

Appendix 6. Themes.

a) Tools, resources and types of data for better integration.

Theme 1: Geospatial Data and Mapping	Theme 2: Data Collection and Observation Tools	Theme 3: Data Access and Updates	Theme 4: Visual and Communication Tools	Theme 5: Implementation and Monitoring

• Cartographic data • Maps • Shapefiles • Mapping tools	• Drones • Tide gauges and meters • In-situ observations	• Updated data • Open access to data	• Illustrative images of the SLR evolution • Posters and leaflets	• Inspection of implementation

b). Communication improvements.

Cluster 1: Information Quality	**Cluster 2: Communication and Dissemination**	**Cluster 3: Coordination and Support**
• Accurate information • Comprehensive information • Regular updates of the information	• Local languages • Information dissemination • Communication tools	• Coordination • Capacity building and training

c. importance of other sources of information

Cluster 1: Information and Evidence Quality	**Cluster 2: Risk and Assessment**	**Cluster 3: Urban Planning and Integration**

• Robustness of information • Increase evidence	• Risk assessment	• Data integration into urban planning • Complement urban planning • Accurate urban planning

d). Information available in national reports.

Cluster 1: Information Availability and Completeness	**Cluster 2: Information Sufficiency for Urban Planning**
• No information available for Maputo • Incomplete information • Lack of regular updates on available information	• Sufficient information for integration into urban planning • Not sufficient for integration into urban planning