Climate adaptation in Maputo, Mozambique:

Coastal hazards, informal settlements and communicating risk

Maputo City. Image source: ThinkWell (2021)

Submitted by Emily Willoughby to the University of Exeter as a dissertation for the degree of Master of Science in Global Sustainability Solutions

60 Credits

"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 Exeter University or elsewhere without specific authorisation."

Emily Willoughby

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My wonderful family and friends. Thank you.

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Abbreviations

DRR: Disaster Risk Reduction

ENAMMC: Estratégia Nacional de Adaptaçáo e Mitigaçâo de Mudanças Climáticas (National Climate Change Mitigation and Adaptation Strategy)

FREMILO: Frente de Libertação de Moçambique (Front for Liberation of Mozambique)

IFRC: International Federation of Red Cross and Red Crescent Societies

INAM: Instítuto Nacional de Meteorologia (Mozambique National Meteorology Institute)

INGC: Instítuto Nacionale de Gestão de Calamidades (National Institute of Disaster Management)

IPCC: The Intergovernmental Panel on Climate Change

MMC: Maputo Municipal Council

OPALS: Oppenheimer Programme in African Landscape Systems

PARPA: Action Plan for the Reduction of Absolute Poverty

PDRRD: Plano Director Para a Redução do Risco de Desastres (Master Plan for Disaster Risk Reduction).

PPM: Parts per million

QPR: Quadro de Políticas de Reassentamento

SST: Sea-surface temperature

SWIO: South West Indian Ocean

UN: United Nations

UNDP: United Nations Development Programme

UNFCCC: United Nations Framework Convention on Climate Change

UNISDR: United Nations International Strategy for Disaster Reduction

Abstract

Mozambique is highly vulnerable to coastal hazards such as floods, cyclones, storms and sea-level rise. 70% of residents in Maputo, the country's capital, live in informal settlements across the city. These residents face pre-existing vulnerabilities such as poverty, inequality, lack of education and barriers to formal employment. The impacts of climate change are set to present further challenges and devastation for this population. Informal settlements have proliferated in Maputo since 1975, owed to the absence of formal planning and other factors. Climate change impacts are well documented for the area, however there is a disconnect between science and action for climate adaptation, particularly in urban planning. This study adopted three methods to support research aims: creating maps using remote-sensing data, analysing national and local policy, and interviews with academics, practitioners and urban planners. This project demonstrates that urban planning has a key role in climate adaptation, then identifies barriers to communicating climate risk and highlights mechanisms that could help overcome these barriers.

1. Introduction

In May 2022, atmospheric carbon dioxide reached 420 parts per matter, the highest recording of carbon dioxide in the Earth's atmosphere to date (Monroe, 2022). Rising carbon emissions are resulting in a rising global temperature, subsequently causing a range of environmental impacts across the world. Emissions are rising despite international collaborative promises like the 2015 Paris Agreement, in which nations across the world committed to join an international effort to limit the global average temperature change to 1.5 degrees Celsius above pre-industrial levels to stop impacts associated with dangerous levels of climate change projected within 2 degrees of warming.

While the climate emergency is global, climate impacts are disproportionately and unfairly devastating poorer and disadvantaged communities, often found in the global South (ICLEI, 2019b). Throughout this project, the use of the term 'global South' exceeds the geographical South and "references an entire history of colonialism, neo-imperialism, and different economic and social change through which large inequalities in living standards, life expectancy and access to resources are maintained" (Dados and Connell, 2012:13, in Bhan, et al. 2018:14). In the realm of urban planning, theories originating from the global North with localised assumptions on socio-economic contexts were often regarded as being valid internationally (de Satgé and Watson, 2018), however this is now rightly criticised by postcolonial thought, and therefore knowledge creation on urban planning from and about the global South is in its infancy (Bhan, et al. 2018).

Mozambique faces many hazards including droughts, floods, tropical cyclones, epidemics, erosion and landslides (MICOA, 2007). This project focuses specifically on coastal hazards that

present challenges to informal settlement residents in Maputo. Maputo, the country's capital, is particularly vulnerable to a number of coastal hazards including storm surges, cyclones, flooding and sea-level rise. 70% of Maputo's residents live in informal settlements (World Bank, 2012) and face challenging living circumstances, which climate change impacts will exacerbate. As such, there is a significant need to make Maputo more resilient, safe, inclusive and sustainable (Croese, et al. 2021).

Maputo was chosen as a spotlight city for this project due to its relevance to a future project. The Global Systems Institute at the University of Exeter is leading the new Oppenheimer Programme in African Landscape Systems (OPALS) after partnering with Oppenheimer Generations Research and Conservation in a £2.3 million research programme. The six-year programme is designed to provide a strong voice for African communities, land managers and researchers for climate change and develop pathways to create resilient natural and human systems in African landscapes (University of Exeter, 2021). OPALS has four main themes including Supporting Coastal Adaptation, focusing on helping urban planners integrate climate risk in their work through improving information exchange and refining support tools. This research programme focuses on the coastline from Durban, South Africa, to Maputo. The goal of this research project is to provide an insight into potential communication barriers to urban planners in regard to climate change as well as identifying mechanisms that might help overcome such barriers, ultimately supporting future OPALS research.

1.1 Research question and aims

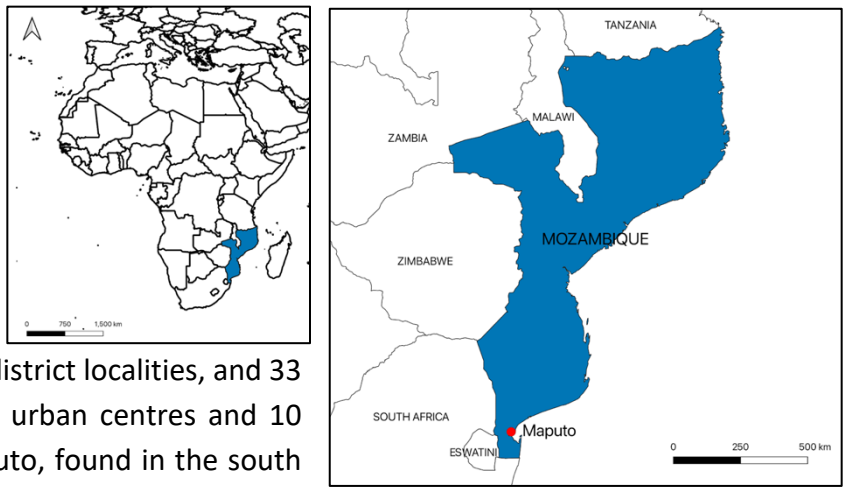
Research question: What are the main challenges associated with communicating climate change risk for adaptation and planning in Maputo, Mozambique?

Research aims:

1. To understand the nature of climate change risks and vulnerabilities for informal settlement residents in Maputo;
2. To use remote sensing to map any urban expansion in Maputo post-independence (1975);
3. To identify issues and barriers in communicating climate change information to urban planners and to identify enabling tools and mechanisms that could assist.

1.2 Study area

Figure 1: Location of Mozambique and Maputo



Mozambique is located on the south-eastern coast of Africa, south of the equator, with 2470 kilometres of coastline stretching between South Africa and Tanzania, facing the Indian Ocean (Mucova, et al. 2021; Kemp et al. 2011). Mozambique is divided into 11 provinces, 128 district localities, and 33 municipalities consisting of main urban centres and 10 provincial capitals including Maputo, found in the south of the country (MICOA, 2007). Maputo's city centre, known as the *cidade de cimento* ('cement city') lies in the south of the city, where the area is heavily urbanised with commercial, business and industrial buildings (Kemp, et a. 2011). The suburban area is generally without structure and is experiencing a growth in population density due to its proximity to the cement city (MMC, 2016). The city is divided into *bairros* (neighbourhoods), each led by a *Secretatio de Bairro* (neighbourhood secretary) (Ensor, et al. 2014). *Barrios* comprise varying levels of urbanisation, land uses and housing precariousness (Frando de Mendonça, 2022). Finally, the peri-urban area has traces of rurality and has an agricultural presence (MMC, 2016).

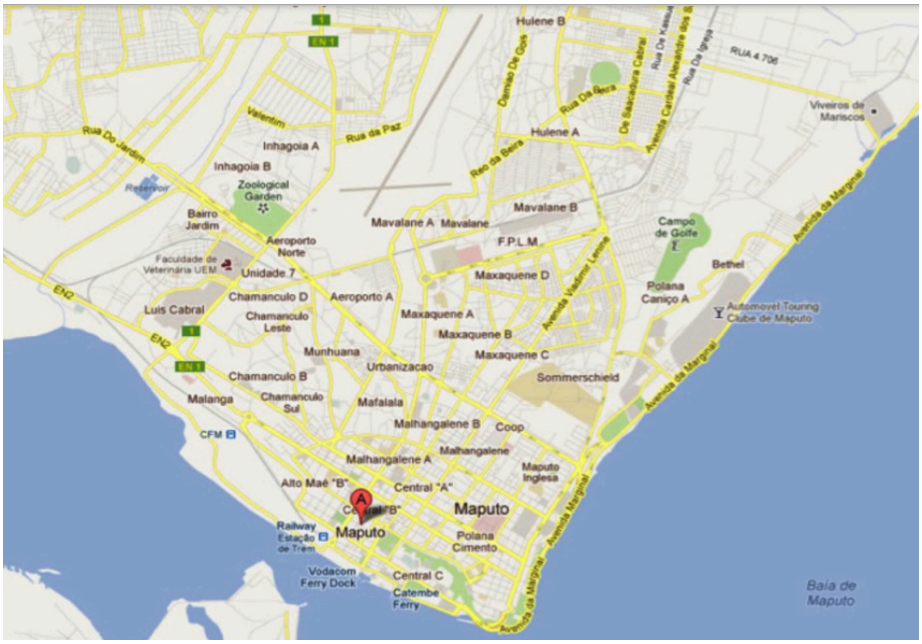


Figure 2: The *bairros* of Maputo. Source: Raimundo, et al. 2018

2. Literature review

2.1 Climate change impacts in Mozambique

The impacts of climate change are well documented for Mozambique. The country is exposed to a plethora of environmental hazards such as cyclones, flooding, drought, sea-level rise, landslides, the impacts of which are determined by factors including emergency response, disaster risk reduction and adaptive capacity. This section considers the extent to which Mozambique and Maputo are exposed to coastal hazards, with subsequent sections considering adaptive capacity and vulnerabilities.

2.1.1. Cyclones

Cyclones present the most significant risk to the country, affecting two million people on average each year (World Bank, 2019). Mozambique is exposed to cyclones due to the tropical storm activity that occurs within the South West Indian Ocean (SWIO) basin, the second-to-third most active in the world for the generation of tropical cyclones (Tulet, et al. 2021). Tropical cyclones are "low-pressure systems intensely rotating cyclonically that form over tropical areas" (Ibebuchi, 2022:33), and the Mozambique Channel experiences frequent cyclonic activity. On average, two tropical storms or cyclones enter or are formed in the Mozambique Channel every year, encouraged by favourable sea surface temperatures of 26-28 degrees Celsius during austral summer (Kolstad, 2020; Ibebuchi, 2022).

The cyclone season falls between September and April, during which time the generation of cyclones is unevenly distributed, as more than half anticipated in this time develop in January or February (Terry, et al. 2013). Additionally, cyclones generated in this time are likely to have a greater sinuosity. Sinuosity measures a meandering distance from a linear distance and is found to present challenges to forecasting while increasing the storms' longevity (Terry and Feng, 2010; Tulet, et al. 2021). Difficulties in forecasting present serious challenges to planning both anticipatory and emergency response to coastal and inland communities at risk.

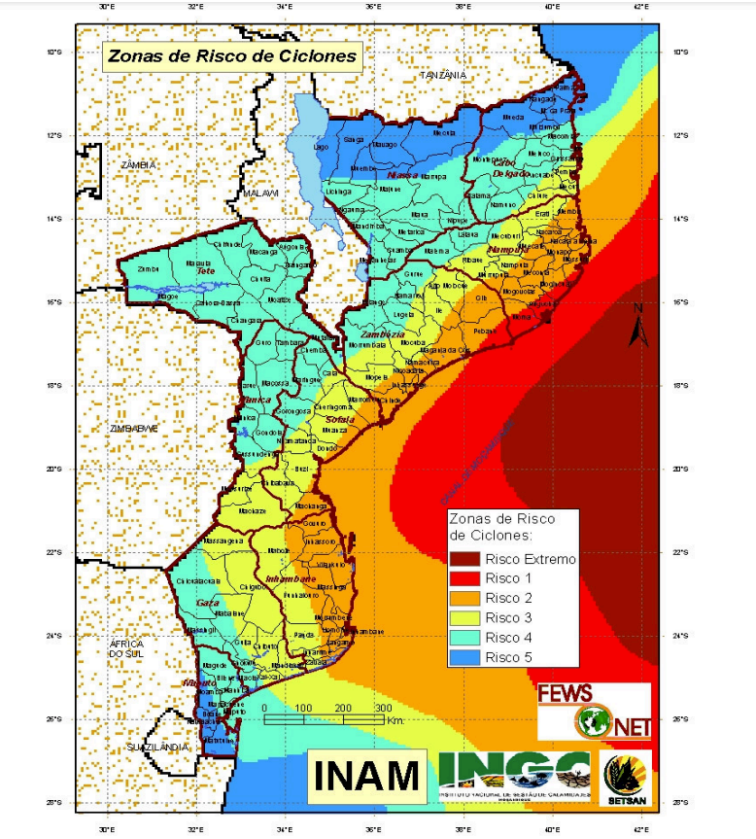
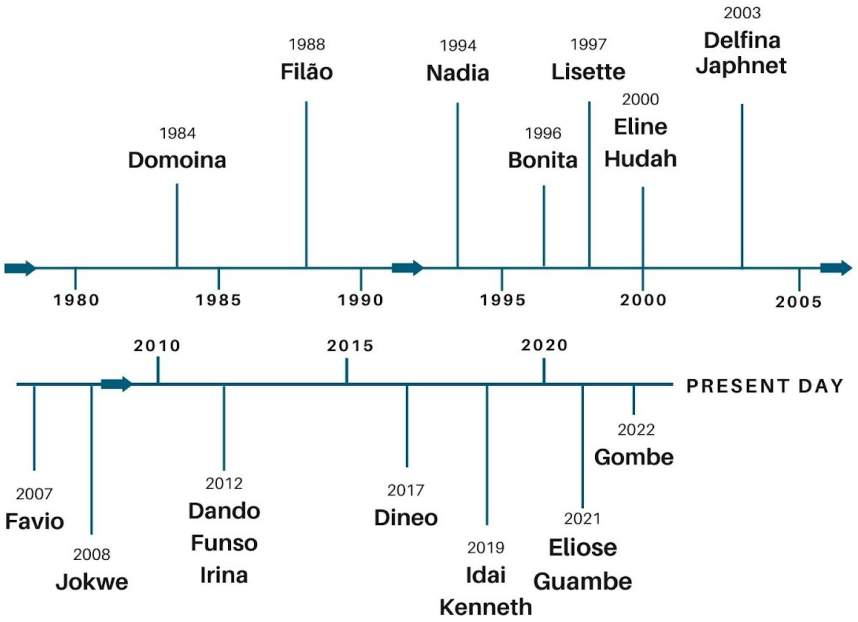


Figure 3: Zones at risk of cyclone activity in Mozambique. Source: INGC 2009.

Figure 4: Tropical cyclones that affected the coast of Mozambique between 1980 and 2022. Data adapted from PDRRD.

Tropical cyclones are one of the strongest and most destructive meteorological events (MICOA, 2007) and for Mozambique, impacts are most significant in coastal areas where the storm retains its force (World Bank, 2019). Areas most at risk of cyclones are visible in Figure 3.



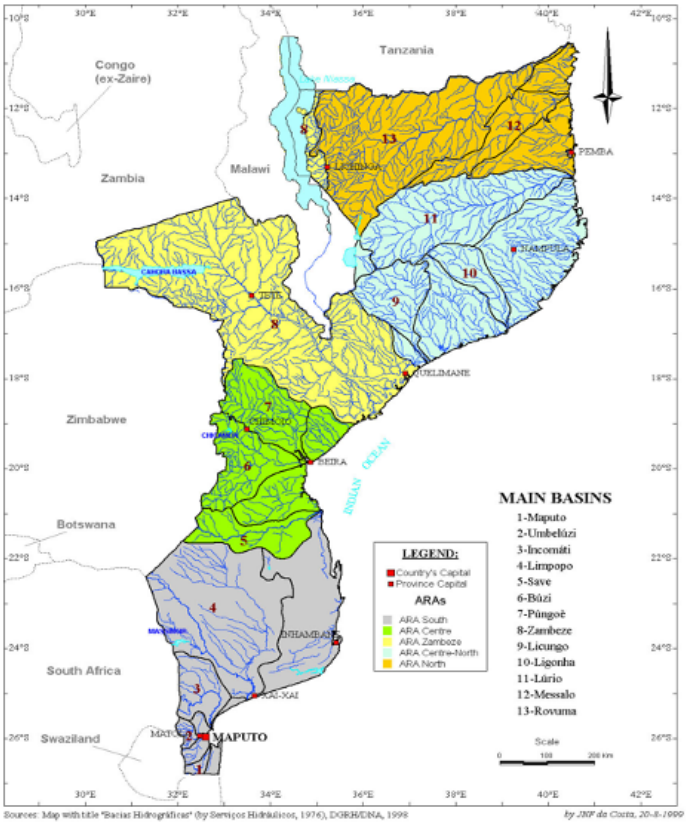
Cyclone observations show indication of an increase in their frequency and intensity with climate change, while models point to a decreasing frequency yet an increase in intensity (Emanual, 2008, in INGC, 2009). Moreover, climate scientists are also exploring the influence of other climate change impacts on cyclone activity. As atmospheric temperatures continue to rise, so does sea-surface-temperature (SST). Considering the influence of SST on tropical cyclones over the SWIO basin, research demonstrates that a 2 degrees Celsius increase in SST will cause the SWIO basin to experience more intense, unpredictable and devastating tropical cyclones (Oguejiofor and Abiodun, 2019; Fairhurst, et al. 2011).

Figure 3 presents Maputo to be in risk zone four from cyclones, a lower risk than is attributed to other coastal cities including Beira, Quelimane and Nacala. While Maputo Bay is sheltered from severe tropical cyclone activity, there are other factors at play that exacerbate the vulnerability of the city (Schleyer and Pereira, 2014).

2.1.2 Flooding

Mozambique has 13 river basins, nine of which are transboundary with neighbouring countries (Figure 5; World Bank, 2005). Mozambique has an extensive history of serious floods, resultant of extreme rainfall during the rainy season and further influenced by cyclones, La Niña and the Inter Tropical Convergence Zone (World Bank, 2011; MICOA, 2007).

Figure 5: River basins in Mozambique. Source: INGC 2009.



Tropical cyclones are typically accompanied by torrential rain, causing flooding in many areas in its path (Fairhurst, et al. 2011).

Mozambique's rainy season is from October to March, while the country's coastline receives between 800 and 900mm of rain each year (MICOA, 2007). This, coupled with the occurrence of the cyclone season, presents a significant risk to the country (World Bank, 2019). To illustrate, the most recent rainy season brought floods and storms that affected over 47,000 people across the country (Mozambique News Agency, 2022).

Figure 6 presents southern areas of Mozambique, including Maputo, to be at very high risk from flooding. Vulnerability to flooding is compounded by multiple factors in Maputo. Firstly, Maputo lies at the confluence of three rivers: the Maputo, Umbeluzi and Incomati (Zehra, et al. 2019). Heavy rainfall anywhere in these catchments is likely to increase river flows to Maputo (ICLEI Africa, 2021). Secondly, urban development can increase the severity of flooding events as concrete infrastructure restricts rainfall permeability into the ground, and this is exacerbated when areas lack functional rainwater and sewage drainage systems (Williams, et al. 2019).

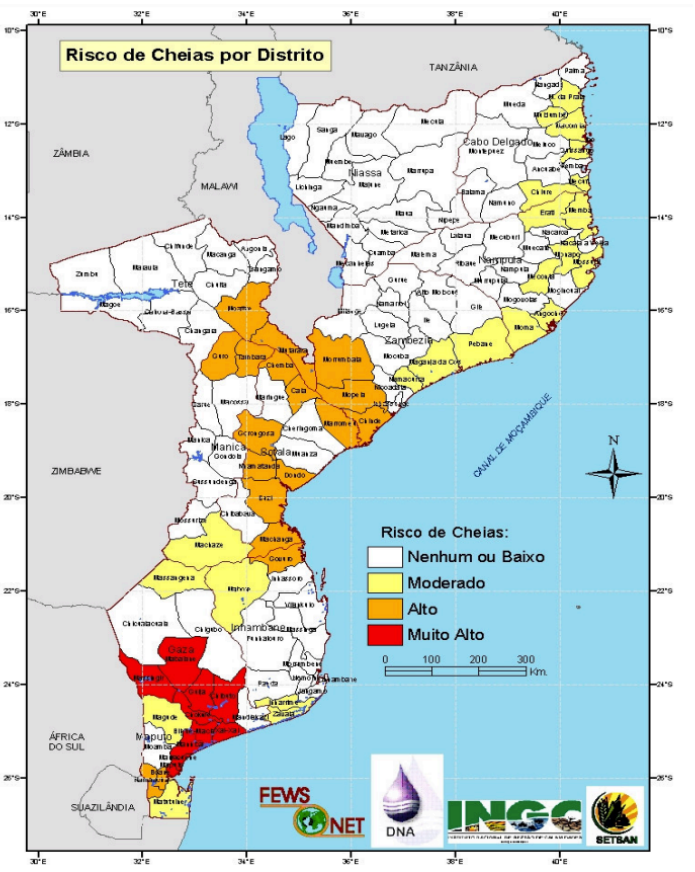


Figure 6: Areas at risk from flooding in Mozambique. Source: INGC, 2009

2.3.1 Sea-level rise (SLR)

SLR is a key impact of climate change. Levels of risk, exposure and vulnerability associated with SLR to low-lying islands, coasts, cities and settlements are presented in a special report by the IPCC (see Oppenheimer, et al. 2019). Over the 20th century, global mean sea level has risen by around 20cm and the rate of rising is accelerating with further SLR inevitable (Met Office, 2017; Allison, 2022).

Climate modellers typically use standardised warming or cooling scenarios, including Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs). RCPs include the different levels of greenhouse gas (GHG) emissions and other radiative forcings that could occur, while SSPs include different options of how the world might respond to climate change (Hausfather, 2018). SSPs range from a fully sustainable society to a business-as-usual approach, whereby fossil-fuelled development is still rife. RCP8.5 is a pathway whereby no intervention has taken place for limiting fossil fuel production, and under this approach the IPCC report states that the rate of SLR will be 15mm yr-1 in 2100 and could exceed several cm yr-1 in the 22nd century (Oppenheimer, et al. 2019). While SLR will inevitably vary by region, mean sea level is projected to rise in Maputo under all scenarios, even those in line with the 2015 Paris Agreement (Mucova, et al. 2021). Therefore, SLR is a serious concern for climate and social science researchers, decision makers, campaigners and communities (McMichael, et al. 2021).

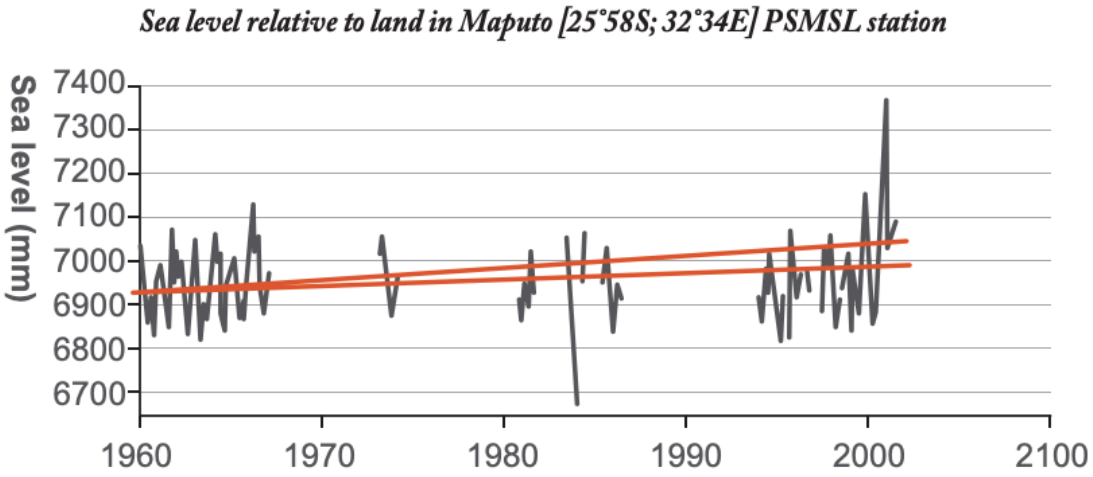


Figure 7: Sea level relative to land in Maputo. Source: INGC 2009

Anthropogenic climate change is set to cause SLR along Maputo's coastline, flooding the lowest lying areas of the city. The risk to Maputo from SLR is exacerbated when considering that regional estimates for SLR along Mozambique's coast are higher than global estimates for all SSP pathways (Mucova, et al. 2021). Minimal historical sea level data is available for Maputo (Figure 7), leading to the cautious use of past trends in projections for the area (INGC, 2009). If a low SLR scenario manifests along the coast of Mozambique, tropical cyclones will

remain as the main challenge for the country, meanwhile a high SLR scenario presents the "permanent inundation of the coast and low lying areas" (INGC, 2009:1) (see Appendix 1 for SLR projections under low and high SLR scenarios).

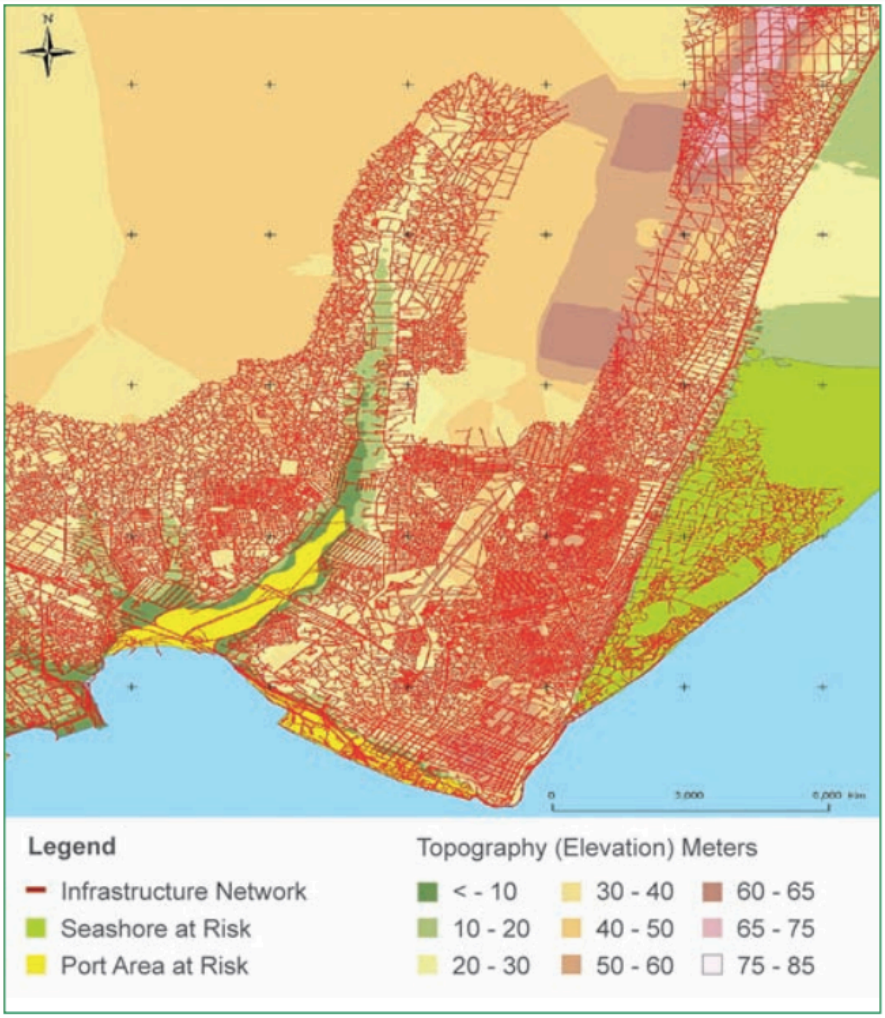


Figure 8: Areas in Maputo vulnerable to SLR in 2030. Source: INGC 2009

Maputo's coastline is already eroding due to the continuous force of the sea, causing significant loss in this area (Castàn Broto, et al. 2013). The green and yellow areas on Figure 8 highlight the areas of the city that are classified as vulnerable to SLR. This projected inundation highlights a serious compromise to the city's infrastructure network in these areas, as a new coastline pushes eastwards into the city and creates a new boundary of the city exposed to the sea. SLR is set to flood the lowest topographical areas, spaces that are often most populated by the urban poor who lack capacity to adapt to climate change (Kemp, et al. 2011).

SLR is also expected to have a significant impact on the destruction caused by cyclones. Researchers modelled incidents of cyclones with different levels of SLR to find that an increased sea level is likely to increase the depth of cyclonic surge in coastal areas, allowing

the storm to become more intense and putting more people and infrastructure at risk (Neumann, et al. 2013). Coastal hazards such as cyclones, floodings and SLR present serious adaptation challenges for Maputo. The INGC (2009) stressed that the combination of these issues during a storm surge at high tide could seriously disrupt Maputo's links outside the city and dangerously hinder emergency response.

2.2 Climate adaptation

Coastal hazards associated with climate change are a reality for Maputo. As for many countries in the global South, Mozambique is tasked with seeking solutions to both mitigate climate change as well as adapt to its current manifestations and anticipated future impacts. Climate adaptation is the significant reduction of risks associated with climate change that have not been avoided by any mitigation initiatives, both locally and globally (UNEP, 2021). The latest Adaptation Gap Report issued by the UNEP (2021) revealed that adaptation measures are increasingly integrated into policy and planning despite uncertainty surrounding future trajectories, stating that implementation requires significant upscaling to avoid further risks, presenting that the adaption gap persists.

Due to the risks, level of exposure and vulnerabilities coastal urban areas experience, action to increase resilience to climate change impacts is gaining momentum. Urban resilience is the capacity for urban areas to absorb and recover when exposed to a hazard while maintaining essential functions and to also be able to adapt to continual change (UN-Habitat, 2019; ICLEI, 2019b). Current literature looks past traditional approaches to climate adaption in search of a holistic, all-encompassing approach. The concept of transformative adaptation reflects the need for profound change within societies (Pelling, 2011), putting people at the heart of adaptation measures in recognising that securing human rights is a key element to increasing resilience to climate change (Miraftab, 2009).

Adaptation is a significant yet important challenge for Maputo that requires commitment and action from the Maputo Municipal Council (MMC). MMC is the main body for urban plans for adaptation, coordinating interventions, training and capacity building, as well as standing as intermediary to access vulnerable residents and community-based organisations (UN-Habitat, 2010). Successful adaptation will not and cannot be addressed solely by international aid (Tiepolo, 2012, in Tiepolo 2014), however the city has seen collaboration with organisations to promote adaptation initiatives.

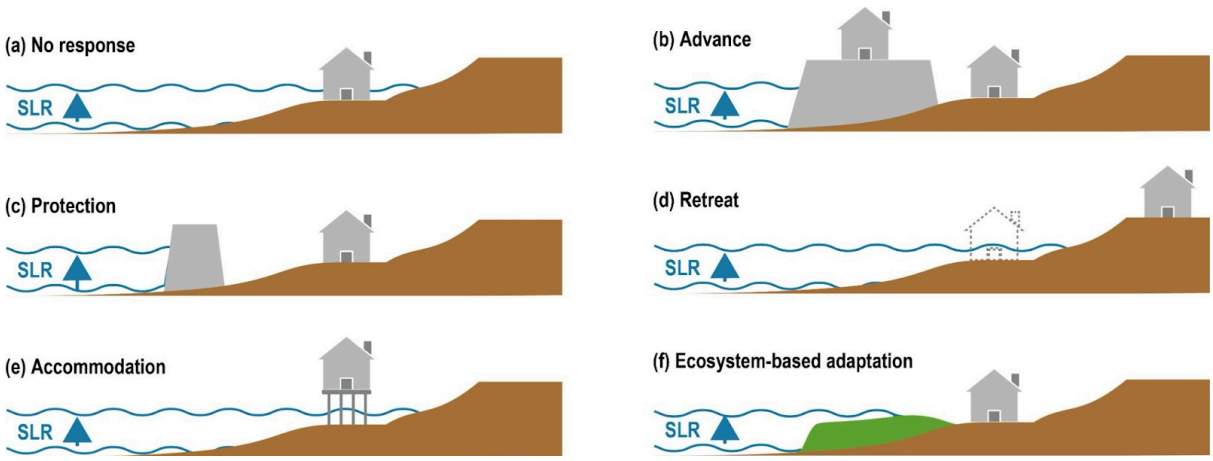
Firstly, UN-Habitat has a strong presence in Mozambique. Since 2002, the UN programme has been working with local government members and communities in Maputo, Nampula, and Quelimane on projects supporting urban planning and infrastructure, urban resilience, informal settlement upgrading and policy development (UN-Habitat, 2019). UN-Habitat has a key role in understanding the resilience of Maputo through the City Resilience Profiling Tool

(CRPT). CRPT helps to identify actions that can be taken to help the city prepare for challenges that present risk to residents. Through this tool, a methodology has been established to gather and analyse data largely surrounding who is impacted and what measures are already in place to mitigate such challenges that might have gone unnoticed to MMC (ICLEI and C40, 2018).

Secondly, ICLEI is a network of local and regional governments committed to sustainability across the world. ICLEI has a strong presence in Maputo, having funded research and capacity-building projects to encourage sustainable development (research participant, 2022). Maputo was involved in the Future Resilience for African Cities and Lands (FRACTAL) project, hosting learning labs and facilitating information exchange amongst urban planners, academics and local residents. While the project is now over, ICLEI-Africa (2012) have encouraged those involved in the project to continue to communicate and build on their networks throughout actions for adaptation.

As coastal hazards present an ongoing threat to Mozambique and Maputo, it is important to consider emergency response and early warning systems as part of an adaptation approach. In Mozambique, the *Instítuto Nacional de Meteorologia* (Mozambique National Meteorology Institute) (INAM) is part of the Ministry for Transportation and Communication. It provides twice-daily weather forecasts to the *Instítuto Nacionale de Gestão de Calamidades* (National Institute of Disaster Management) (INGC) and to residents. INAM is equipped with a meteosat receiving station, allowing access to information that is updated every fifteen minutes (research participant, 2022). The INGC created early warning systems across the country to enable people to be aware of disaster risk and take action accordingly. In March and April 2019, cyclones Idai and Kenneth caused widespread destruction in Mozambique and beyond, with disaster relief agencies calling for greater investment in early warning systems within the country (IFRC, 2020). Established in 1999, over the years the INGC has broadened its scope by looking beyond disaster management to include disaster risk prevention and understand vulnerabilities (Artur and Hilhorst, 2012).

Figure 9: Options for methods to adapt to SLR, from no response to ecosystem-based adaptation Source: Oppenheimer, et al. 2019. P15.



There are many ways in which cities can adapt to coastal hazards. For example, the IPCC presents a number of options for low-lying coastal areas to adapt to SLR, ranging from no response to managed retreat and ecosystem-based adaptation (Figure 9). However, the extent to which communities can adapt to climate change impacts is severely restricted by their adaptive capacity.

2.2.1 Adaptive capacity

Adaptive capacity is the extent to which people, institutions and sectors are able to adapt and become more resilient to climate change impacts (UN-Habitat, 2010). For Maputo, adaptive capacity is strongly influenced by inequality, governance and poverty (Castàn Broto, et al. 2013). The World Bank (2021) states that Mozambique's elevated macroeconomic volatility, experience of climate change impacts and Covid-19 elevated poverty rates to 63.3% of the population. This is a considerable proportion of Mozambique's population that lack adaptive capacity due to high levels of poverty.

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

Considering the quantity of climate change related events in Maputo, actions for adaptation to climate change is an urgent requirement. As Maputo is subject to tropical cyclones,

flooding and SLR, there is no single adaptation approach that can address all vulnerabilities, as each hazard brings different impacts and consequences and require extensive consideration and assessment.

Mozambique has received recognition for aligning its Master Plan for Disaster Risk Reduction with the Sendai Framework (UNDRR, 2019). This framework outlines four priorities for action that coincide with Mozambique's plan: (i) understanding disaster risk, (ii) strengthening disaster risk governance, (iii) investing in disaster risk reduction, and (v) enhancing preparedness (UNDRR, 2015). Mozambique has also submitted a voluntary national review to the UN for progress to Agenda 2030, presenting concern at the quantity of natural disasters affecting the country, requiring an improvement in strategic mechanisms to "deal with climate change", meanwhile also identifying urban planning as an institutional mechanism to reduce disaster risk (Republic of Mozambique, 2020:2).

2.3 Urban planning in the global South

2.3.1 The role of urban planning in climate adaptation

The UN (2018) estimates that two out of three people, reaching nearly 2.5 billion people globally, will live in urban areas by 2050. Often, coastal and other hazards are attributed to climate change impacts, ignoring other risk, exposure and vulnerability components such as urbanisation and urban planning (Mason, et al. 2020). As urban planning determines land-use in cities, it has a crucial role in contributing to future resilience to climate risks (C40 Cities, 2020).

Urban and peri-urban planning is conducted by a team of professionals and activity is driven by demand for various land-use types, including housing (Mills, et al. 2010). By nature, planning is a future-focussed discipline (Oppenheimer, et al. 2019). Good urban planning policy and implementation can address both climate mitigation and adaptation through utilisation of strategic planning tools and good understanding of the local urban area (Hurlimann, et al. 2021; Newman, 2020).

2.3.2 The legacy of colonialism

The legacy of colonialism persists in the laws of many planning systems across the global South, rendering them inappropriate in many contexts (de Satgé and Watson, 2018; Berrisford, 2014). Many countries in the global South still use variations of urban planning approaches that emerged from the UK, Europe and the US in the early 20th century which focussed predominantly on urban aesthetics such as order, formality and symmetry, efficiency measures such as the specialisation of areas, as well as slum removal and the creation of open green spaces (de Satgé and Watson, 2018). These approaches often excluded different groups from the city, owed to discriminatory views and regulations (Skinner and Watson, 2018). African governments have continued to adopt colonial land management tools and practices, reinforcing colonial planning legacies (UN-Habitat, 2009, in Battersby,

2018). To illustrate, in Maputo urban design and zoning were intended to "closely monitor the activities of 'native' urban dwellers in the 'white city'", barring indigenous populations to local governance, economic opportunities and social infrastructure in the city (Kamete and Lindel, 2010:890).

Mozambican cities, including Maputo, are recognised for their duality: having two realities coexisting within one city (Fernandes and Mendes, 2012). Mozambique experienced a long colonial ruling from Portugal, the legacy of which is still evident in Maputo. Colonial powers adopted European planning regulations, creating a socio-racial division of the city and ultimately excluded the African population from living in it (Franco de Mendonça, 2022). Formally known as Lourenço Marques, Maputo's *cidade de cimento* ('cement city') was designed to cater for the colonialists who actively monitored indigenous groups to ensure order in the city (Kamete and Lindell, 2010). Maputo's experience of rural-to-urban migration in the 1970s and 80s brought about densely built neighbourhoods which often lacked sturdy infrastructure, known as *cidade de caniço* ('reed city'), significantly contrasting with modernist buildings that emerged in Lourenço Marques' colonial centre (Castàn Broto, et al. 2013). Furthermore, since independence from Portugal, *Frente de Libertação de Moçambique* (Fremilo) established party networks at the *bairro* level to maintain control of political and economic activities in urban areas. The city is marked by socio-spatial divisions in access to sanitation services and the unequal distribution of environmental risk (Biza, et al. 2022). Today, 70% of Maputo's residents live in informal settlements across the city and are subject to poverty, exclusion from formal education and the formal economy, live in hazardous locations in homes with conditions detrimental to human health.

2.4 Informal settlements

It is estimated that close to one billion people live in informal settlements across the world (Satterthwaite, et al. 2018). Urban centres in Sub-Saharan Africa are growing fast and expanding beyond administrative boundaries, as poorer individuals and families seek land outside of municipal regulations and settle on land with no tenure security in what is recognised as informal settlements (de Satgé and Watson, 2018). Informal settlements have a key role in shaping urban landscapes through the "incremental, unauthorised and self-organised production of new urban neighbourhoods" (Dovey, et al. 2020:1). Therefore, informal settlements can range from high-density housing in the middle of the city or spontaneous settlements on the urban periphery (Menshawy, et al. 2011). Planning laws have often contributed to the exclusion of informal settlement residents to housing and land markets (Dodman and Satterthwaite, 2020). As residents were, or continue to be, viewed as a problem and informal settlements viewed as spaces of "great complexity and low economic benefits" for governments, residents were not considered in urban development plans due to limited government interest (Wojtowicz-Jankowska and Kalfouni, 2022:21).

The number of people living in informal settlements is expected to increase with population rise and the ongoing lack of affordable housing within cities (Zerbo, et al. 2020; Satterthwaite, 2018). In the global South, it is common for 20-50% of a city's population to live in informal settlements (Hardoy, et al. 2001, in Dodman and Satterthwaite, 2020), with estimates that one in seven people could live in informal settlements by 2030 (Walncycki, 2022a). The UN (2019) predicts that the number of informal settlement residents could reach as high as three billion people.

2.4.1 Inequality

Informal settlement residents are subject to extensive inequalities. Firstly, residents experience significant health deprivation and inequalities. Mozambique has a considerable portion of the population living in "absolute poverty, food and nutritional insecurity, with serious threats to human health" (MICOA, 2007:10). By simply living in an informal settlement, human health is compromised. As houses are typically built adjacent to one another, in close proximity and without adequate sanitation and drainage, and illnesses and diseases are common (Williams, et al. 2019). Outbreaks of epidemics such as cholera, malaria, dysentery and Covid-19 add an additional burden (MICOA, 2007). Moreover, the MMC has been urged to plan for vector-borne diseases associated with climate change including malaria, chagas disease, Lyme disease and onchocerciasis (Kemp, et al. 2011). Recent research explains that 58% of infectious diseases have been, at times, aggravated by climate change impacts (Mora, et al. 2022).

Secondly, informal settlements also magnify gender-related inequalities (Weimann and Oni, 2019). For example, women are often the most affected by challenges of living in informal settlements, including poor sanitation, a lack of access to clean water, food insecurity and are greatly exposed to health risks (Cities Alliance, 2017; Walnycki, 2022b). Research in Freetown, Sierra Leone highlighted how women experience informal settlements; women reported poor individual and public facilities such as toilets, fear and discomfort, and having no one able to help them access basic services or manage paid employment demands, coupled with often having significant care duties for family members (Conteh, et al. 2021; Meth, 2017).

Thirdly, informal settlement residents face environmental inequalities. Most settlements occupy areas that are outside of land regulation on high-risk spaces such as steep slopes, floodplains and watersheds (Satterthwaite, 2018). This also includes coastal and riverine areas and therefore exposing residents to some of the greatest impacts of climate change (French, et al. 2020). Climate change and inequality are recognised as being part of a vicious cycle. To illustrate, inequality can be exacerbated through three main avenues: an increase in exposure to climate change, the increase in susceptibility to damage caused from a natural hazard and finally, a decrease in their ability to cope and recover from climate change impacts (Islam and Winkel, 2017). The duality of Maputo is reinforcing inequalities, and is subjecting

informal settlement residents to greater risk from climate change (Castàn Broto, et al. 2013:638). Figure 10 provides a visualisation of how hazards, vulnerability, exposure and adaptation interact and contribute to risk. In Maputo, morbidities are associated with poor sanitation, water quality and poor nutrition (Kemp, et al. 2011). On top of this, residents typically lack representation in decision-making by governments and so are likely to face socioeconomic, environmental and political exclusions that cause ill health (Walnycki, 2022a).

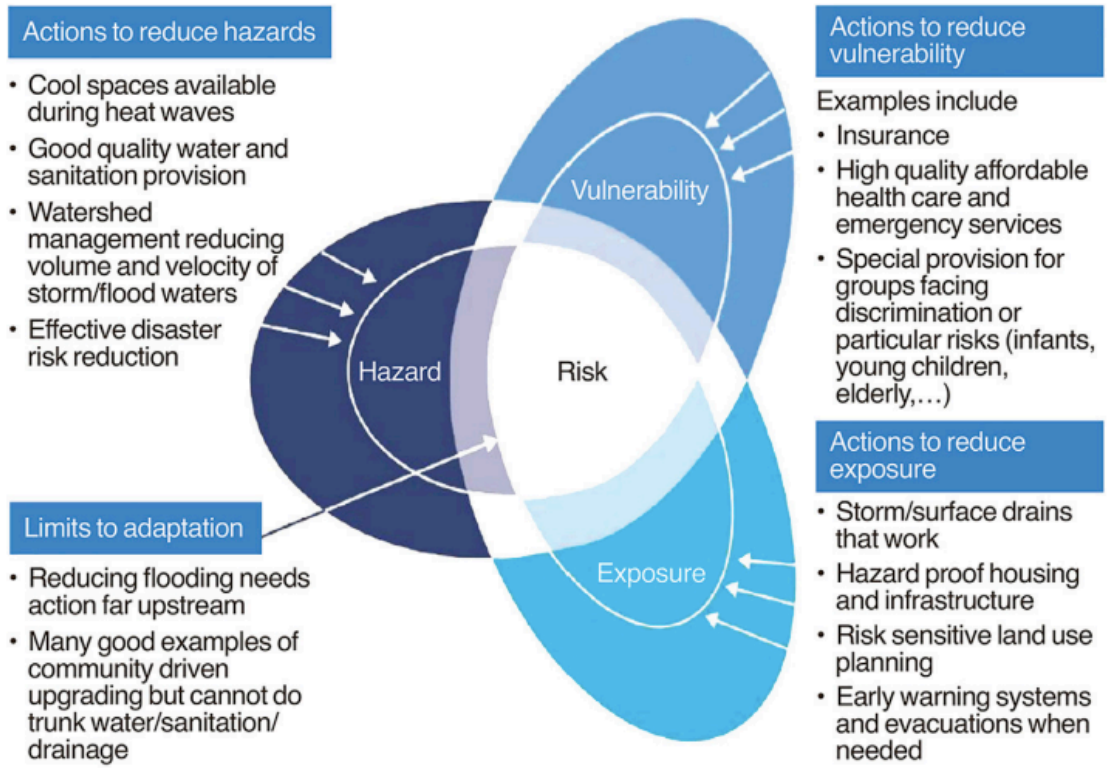


Figure 10: Addressing hazards, risks and vulnerability in informal settlements. Source: Satterthwaite, et al. 2020

While Figure 3 presents Maputo to be in one of the less-risk prone areas for cyclones due to its reduced exposure, the vulnerabilities that informal settlement residents already face allow cyclones to still present a significant risk to this group. Meanwhile, their exposure and frequent experience of floodings are compounded by their low adaptive capacity. For an already vulnerable group, climate change will exacerbate inequalities, heightening the need for upgrading measures to increase their resilience (Mills, et al. 2010).

2.4.2 Upgrading

There have been a range of responses to informal settlements across the world, as governments, charities and development agencies attempt to implement informal settlement upgrading initiatives. In some instances government's view informal settlements as an urban problem due to their untidy nature (French, et al. 2020), and often perceive bulldozing of settlements a favourable option, often without the accompaniment of onward support for residents (Patel and Satterthwaite, 2022). In fact, de Satgé and Watson (2018:43) present where governments in African urban areas have used planning laws to evict communities and demolish informal housing for not meeting the "orderly requirement". Figure 12 highlights various upgrading initiatives that governments and organisations have adopted. This can range from including piped water and toilets in every home, to community-led upgrading that considers future climate change risks.

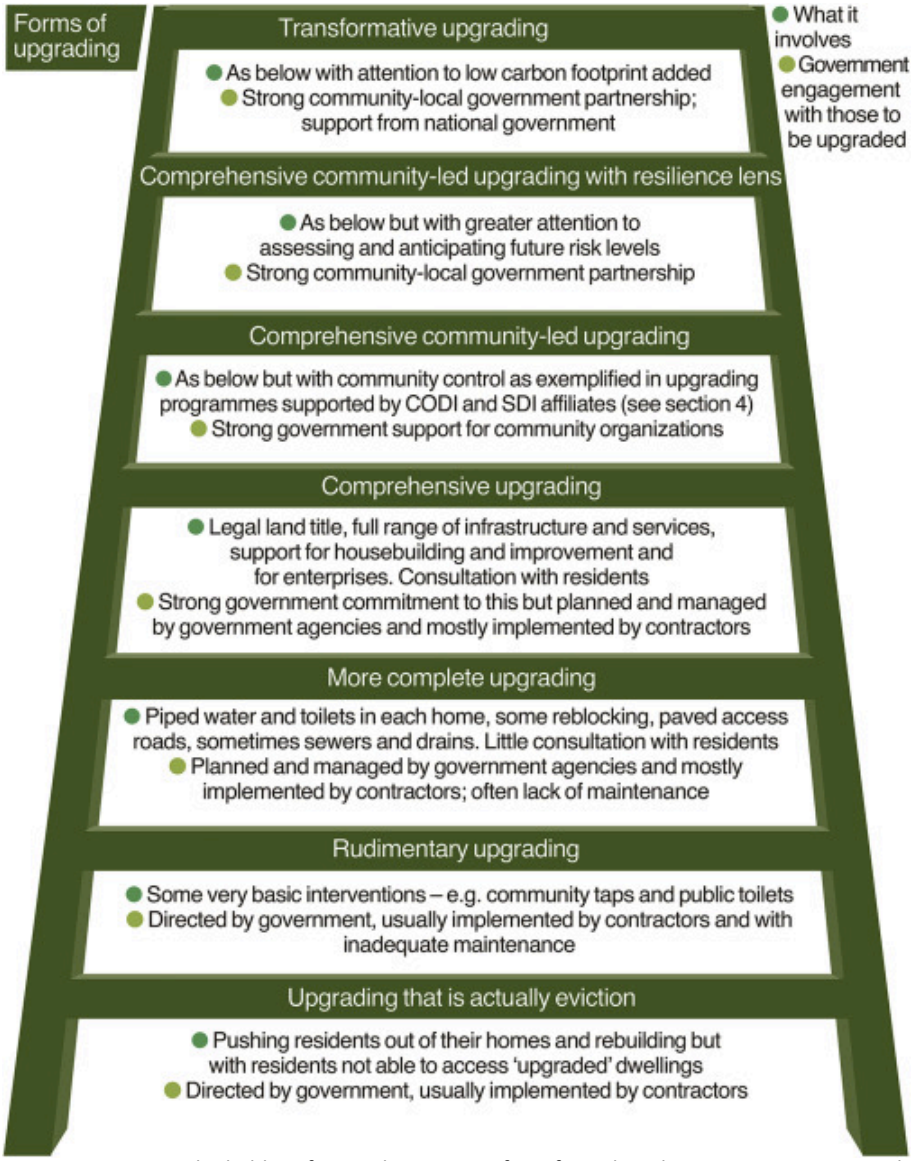


Figure 11: The ladder of upgrading options for informal settlements. Source: Satterthwaite, et al. 2020

Outside of Figure 12, relocation and resettlement are also options that governments consider in managing vulnerable communities or households. Relocations can be understood as the "physical movement of people instigated, supervised and carried out by state authorities (whether national or local)" and can be temporary for emergency evacuation or permanent (Ferris, 2014:8). Permanent relocations are known as resettlements, and are the "comprehensive movement of people… it involves not only new housing and services, but also new social and economic relations, and new challenges such as access to work and social cohesion" (Johnson, et al. 2021:319).

Climate change impacts will cause communities to be displaced, whether through planned intervention or ad hoc events (Forsyth and Peiser, 2021). There is a growing body of literature examining resettlement projects as a climate adaptation strategy (Arnall, 2016), and while it is not a new approach, there are many motivations behind programmes from governments that could raise questions surrounding legitimacy (Mortreux and Adams, 2015). Colonial rule of Maputo historically failed to issue building permits for African residents settling in the 'reed city', meanwhile informal houses built in these areas were subject to relocation in the midst of the colonial centre's development and expansion (Franco de Mendonça, 2022).

Resettlement literature consistently acknowledges that this process must meet a number of criteria to ensure the success for residents. Lavell (2021) states that it must absolutely reduce disaster risk and maintain the social and economic advantages present in their original settlement. This is important in government interventions of this kind, as previous resettlement projects have omitted sufficient screenings of current and future climate change impacts, pertaining or reducing the community's vulnerability to environmental hazards (Sherbinin, et al. 2011). Furthermore, if these advantages do not exist in the new area then residents might not consider moving, even if they are presented with opportunities to obtain formal homes, owed to a variety of issues such as price, location and social quality (Satterthwaite, et al. 2020). Moreover, resettlement projects often pay limited attention to sustainable development and are therefore unsuitable for projects trying to increase a community's adaptive capacity (Otsuki et al. 2022).

So far, this chapter has highlighted the risks coastal hazards present to Mozambique and Maputo and identified informal settlement residents as a significant portion of Maputo's population vulnerable to these risks. As aforementioned, 47,000 people were affected by the latest storms in Mozambique's rainy season through incidence of flooding. People are repeatedly subject to coastal hazards. Castàn Broto (et al, 2015) identify a significant gap between rhetoric and policy for current interventions on climate change impacts. For planners in African cities, decision-making is seemingly undertaken with information scarcity (Spaliviero, et al. 2020). Demand for climate information is growing in the global South, however questions have arisen surrounding the appropriate quantity, depth and type of data that should be available and shared (Vincent and Conway, 2021). Moreover, even advances in climate data have been recognised as insufficient to reduce risks of climate impacts. For Mozambique, tropical cyclones can be "accurately predicted at lead times of one to three days" (Engelbrecht and Vogel, 2021:1055). In 2019 tropical cyclone Idai made landfall at Beira, Mozambique, causing destruction across Mozambique, Zimbabwe and Malawi, killing over 1,000 people and causing nearly 110,000 people evacuated to shelters (The Guardian, 2019).

This data-action gap presents a serious challenge for increasing informal settlements' adaptive capacity. Urban planning can be an effective tool for informing the city's role in climate adaptation, however questions arise surrounding the barriers to this implementation.

3. Methodology

For this project, research design consisted of both qualitative and quantitative data collection to allow for an in-depth exploration of the research questions and aims. This project adopted three methods: remote sensing was used to map urban change, key themes were analysed in national and municipal strategic and legislative documents, followed by interviews with academics, practitioners and urban planners. Adopting mixed methods can help to broaden the dimension of a study and illustrate the complexity of the research (Teye, 2012; Peters, 2017).

3.1 Ethical considerations and positionality

Firstly, this project required ethical approval (Appendix 2) before research began, as per university guidelines. As this project included interviews, consent forms were sent to all participants before any interviews were arranged to explain the project, present research aims, established why individuals were approached, their rights as research participants and addressed confidentiality and anonymity.

As with most qualitative research, the knowledge and understanding of cultures is created through adopting various methods that can contribute to the understanding of that topic (D'Silva, et al. 2016). However, researchers can have an influence on this process. A researcher's positionality can impact the way research is conducted, analysed and interpreted, ultimately impacting research outcomes (Merson, 2022). As such, researchers should not make assumptions about other perspectives or inflict their views onto participants (Holmes, 2020). Therefore, adopting a reflexive approach through the use of self-assessment is integral to contemporary research. This involves "a self-monitoring of, or to, our thoughts, feelings, and actions" throughout the project (Corlett and Marvin, 2018:3). While positionality can alter between contexts (Holmes, 2022), as a white, British, English-speaking, mid-twenties, cisgender female, enrolled at a Russell Group University, I am aware that my positionality had an impact on research activities. While not directly engaging with vulnerable individuals in Maputo, interviews discussed vulnerabilities faced by informal settlement residents at length. However, this project was developed with the guidance of Dr Ricardo Safra de Campos and Dr Andy Cunliffe to ensure sensitivity and the appropriate handling of data and knowledge generated.

3.2 Remote sensing

Remote sensing “makes use of the interaction of energy waves to measure objects or materials from a distance, without physical contact” (Blumenthal, 2019:1) and creates new sources of information for land-use understanding and management, including in urban areas (Masser, 2001). To visualise urban change for Maputo and the wider provincial area, maps were created using free data from the Global Human Settlement Layer (Pesaresi and Politis, 2022). The GHS-BUILT-S R2022A is a spatial raster dataset presenting built-up surface estimates between 1975 and 2030, derived from five multiple-sensor and multiple-platform satellite imageries, from Sentinel2 composite and Landsat (Schiavina, et al. 2022). Data was downloaded for Maputo Province at 100m resolution as per the availability of the dataset, from 1975 to 2025 at ten-year epochs. The difference in built-up surface data was calculated between datasets (the change between 1975 and 1985, 1985 and 1995 and so on) and is presented the following chapter.

3.3 Content analysis

To help achieve research aims, a content analysis of national and local policies was conducted. This method was inspired by research by Siddiqui, et al. (2020) who presented a content analysis of how migrant populations were represented in Bangladeshi policies. For this project, policies were analysed in order to ascertain the visibility and representation of informal settlement residents and discussion of their management, and the role of urban planning in climate adaptation. This analysis included five national and four municipal policies and strategies, chosen for their relevance to this project. As this project encompasses cross-cutting themes including climate change, adaptation, disaster risk reduction, poverty, inequality and urban planning, recent policies and strategies surrounding these themes were chosen. One document included is the 2020 Disaster Management and Risk Reduction Law, following a recommendation from a research participant.

3.4 Interviews

This project also included semi-structured in-depth interviews. In-depth interviewing is a good method for “generating detailed data on the experiences, perceptions, emotions, beliefs, and behaviours of respondents” (Teye, 2012:1). Supporting Coastal Adaptation is a key theme of the OPALS programme, and in the development of the programme a partnership of key organisations was established to support future research. This includes Eduardo Mondlane University, and as this project aims to support future OPALS work, interviews were arranged with two members of this University. More participants were engaged through chain-referral, resulting in a total of eight, in-depth, semi-structured interviews. Participants included academics, practitioners and urban planners based in Mozambique and South Africa. Discussions varied in length from 30 minutes to 1.5 hours.

Interview design can be found in Appendix 5. There were twenty questions in total exploring the categories and cross-cutting themes, however the interview allowed for the exploration

of other themes participants wanted to share. As all interview participants were based in Mozambique or South Africa, interviews were held over Microsoft Teams or Zoom depending on participant preference.

Transcripts were analysed using coding. Coding is the structured process of allocating themes to data: assigning labels, words or short phrases directly to transcripts (Peters, 2017; Given, 2008). Coding is used for data reduction, organisation, and analysis (Cope, 2010). In vivo coding makes use of the participants' own words, using the voice of the participants and allowing participants to give meaning to the data (Manning, 2017). In vivo coding is recognised as useful when participants are from different cultures to the researcher as it ensures concepts taken from the data remain close to participants' own words, allowing for no meaning to be inferred out of place (Manning, 2017).

3.5 Study limitations

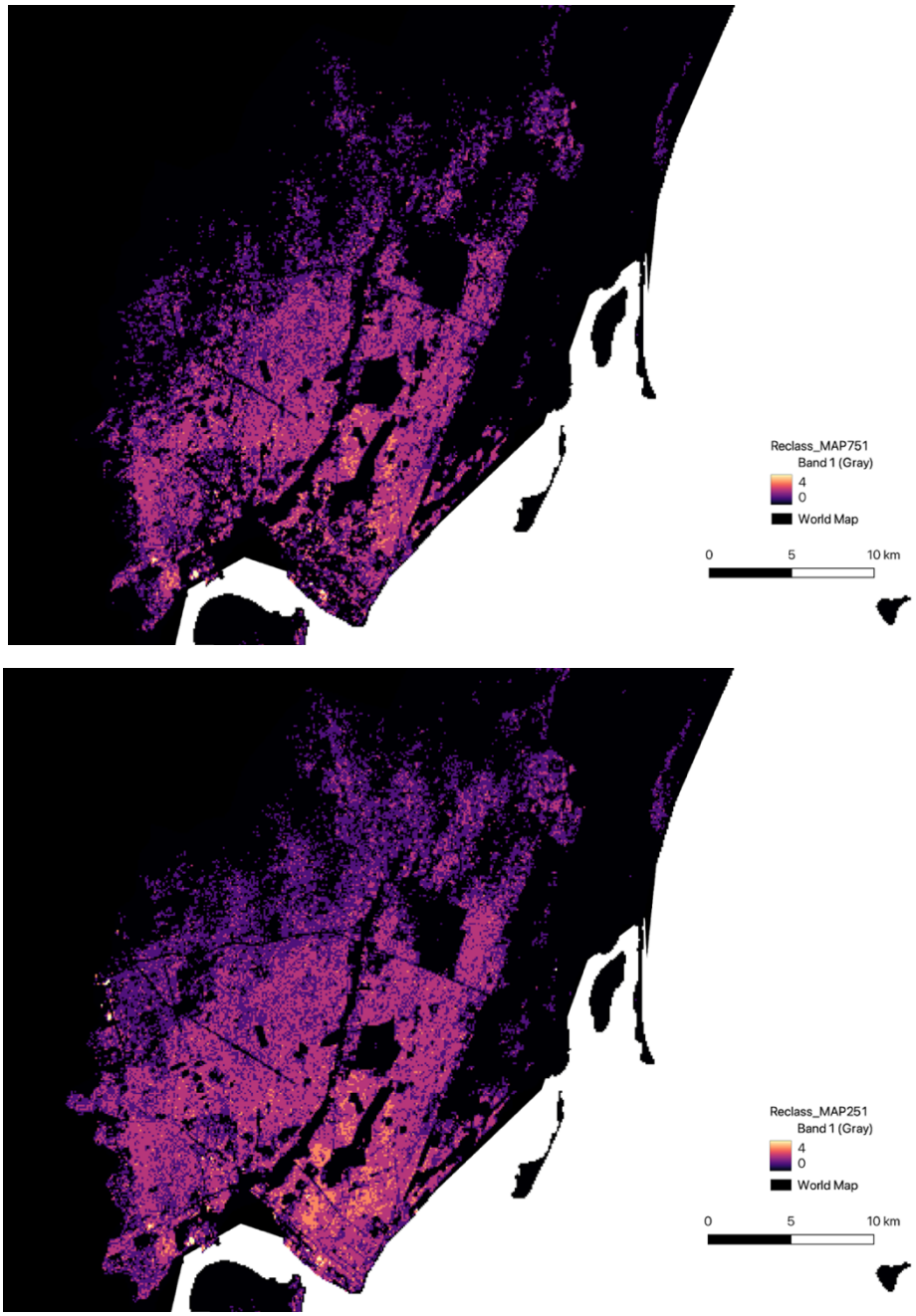
This research was desk-based and had not included a prior visit to Mozambique or Maputo, nor were any interviews face-to-face. Internet connectivity presented occasional issues during interviews however this brought no real problems to the project. I also do not speak Portuguese, one of Mozambique's main languages. For analysing Mozambique's policies written in Portuguese, translation software was used with additional assistance from Portuguese-speaking colleagues. English was not the first language of many participants involved in this study, as such participants were presented Portuguese text explaining that if they felt happier answering in Portuguese they would be welcome to.

4. Results

4.1 Remote sensing

This section shows a visual representation of urban change in Maputo and the wider Maputo Province. The degree to which a 100m squared pixel is urbanised is illustrated by colour. Low surface urbanisation is dark purple, while high urbanisation is bright yellow. Figure 12 shows the difference in urbanisation between 1975 (top image) and predicted linear data for 2025 (lower image). Key observations include that the south of the city (the cement city) is a much brighter than the surrounding dark pink tones, indicating a higher degree of urbanisation, as is consistent with literature. While development on the coastline has only grown marginally, these results still show a significant amount of development on a coastline vulnerable to storm surges and SLR.

Figure 12: Urban built-up surface area in Maputo 1975 (top) and projected for 2025 (bottom).



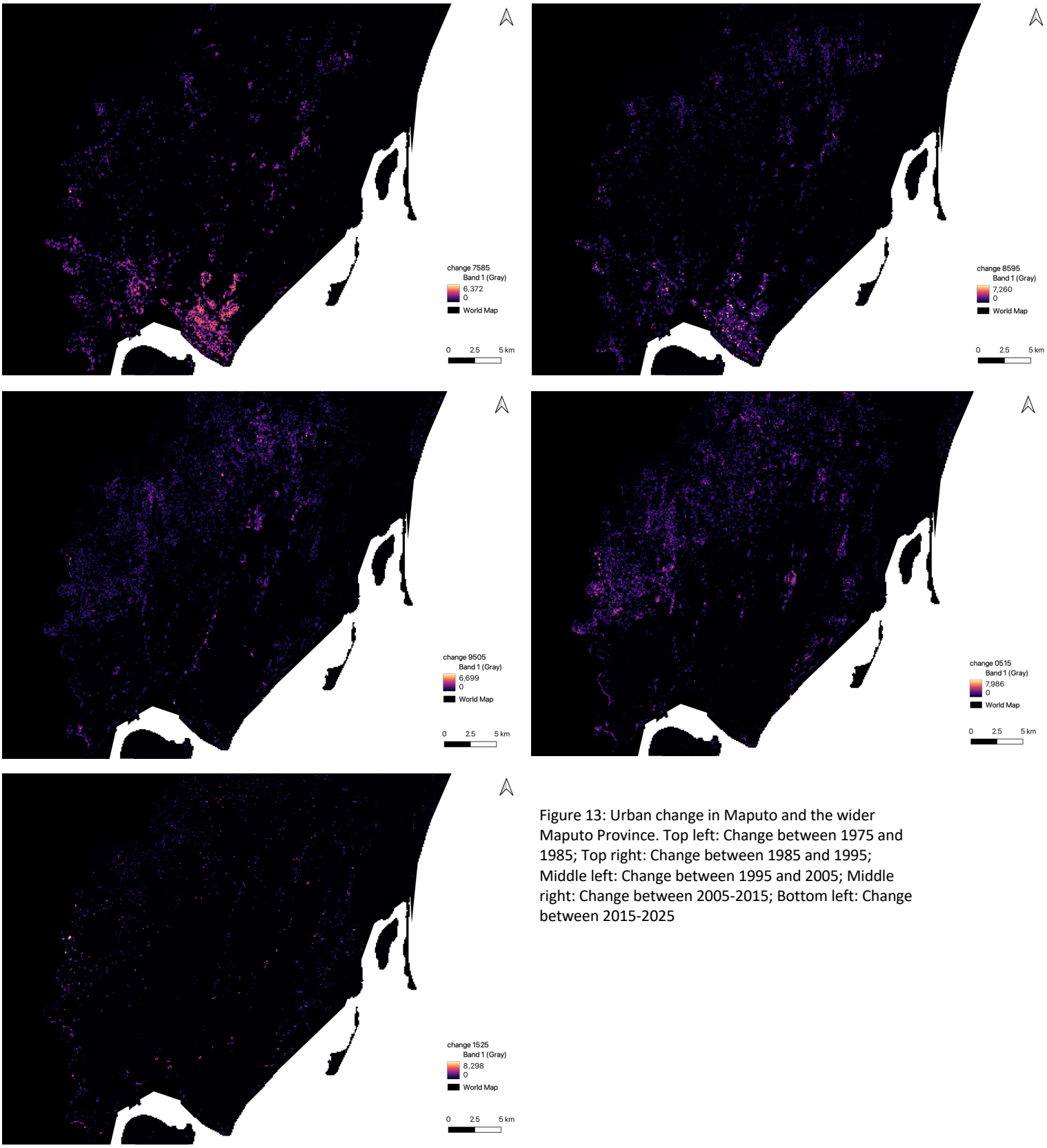


Figure 13: Urban change in Maputo and the wider Maputo Province. Top left: Change between 1975 and 1985; Top right: Change between 1985 and 1995; Middle left: Change between 1995 and 2005; Middle right: Change between 2005-2015; Bottom left: Change between 2015-2025

Figure 13 shows that urbanisation for Maputo was extensive between 1975 and 1995, whereas development between 1995 and 2015 occurred mainly in the urban periphery, in the neighbouring city Matola and along the city's coastline.

4.2 Content analysis

Documents were analysed for implicit and explicit discourses on informal settlements. Understanding the visibility of informal settlements was most focused on here, particularly as there is an "unwillingness of many governments to work with low-income groups" (Moser and Satterthwaite, 2008:v).

Table 2: Current national and municipal policies on informal settlements, climate change, climate adaptation and disaster management

Policy type and title	Year	Issuing Body
National Adaptation Action Plan (NAPA)	2007	Ministry for the Coordination of Environmental Affairs
National Climate Change Mitigation and Adaptation Strategy (ENAMMC)	2013-2015	Ministry for the Coordination of Environmental Action
Law on Disaster Risk Reduction and Management (DRM)	2020	Government of Mozambique
Climate Change and Gender Action Plan (Phase II)	2014	Ministry for Coordination of Environmental Affairs
Action Plan for the Reduction of Absolute Poverty (PARPA II)	2006-2009	Government of Mozambique
Master Plan for Disaster Risk Reduction (PDRRD)	2017-2030	Government of Mozambique
Urban Master Plan of Maputo Municipality	2008	MMC
Maputo's Resettlement Policy Framework	2007	MMC
PROMAPUTO MMDP I	2020	MMC
PROMAPUTO MMDP II	2020	MMC

Table 3: Distribution of discourses on informal settlements in Mozambique and Maputo in policies surrounding informal settlements, climate change, climate adaptation and disaster management. - analysed for implicit and explicit discourses on informal settlements

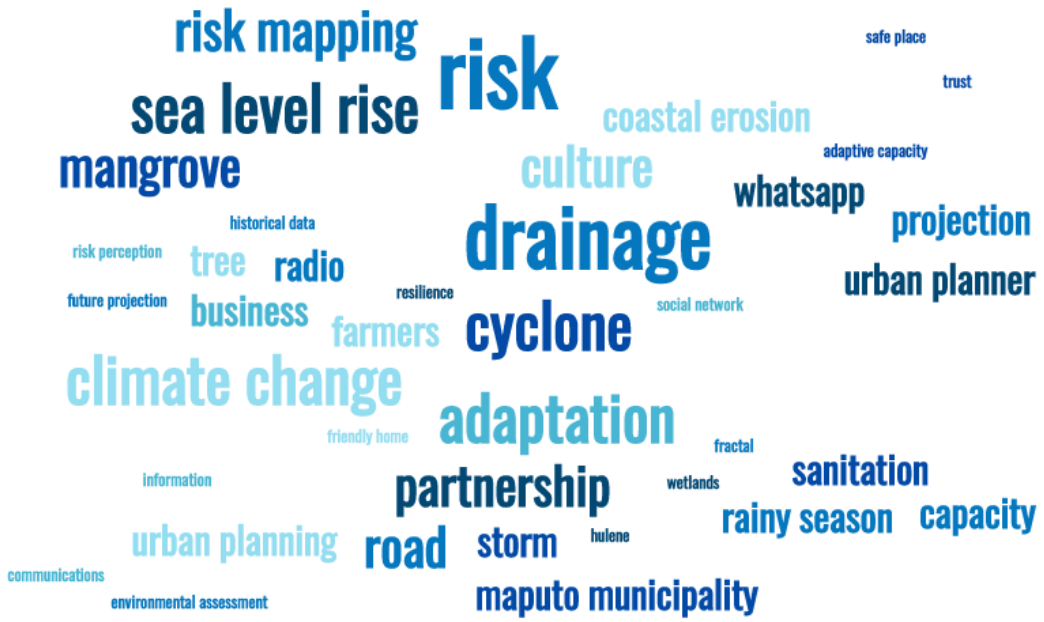
Policy type and title	Conceptualisation of informal settlements			
	Visible	Source of issues	Management/upgrading	Role of planning in adaptation
National Adaptation Action Plan (NAPA)	x		x	x
National Climate Change Mitigation and Adaptation Strategy (ENAMMC)	x		x	x

Law on Disaster Risk Reduction and Management (DRM)	x	x		
Climate Change and Gender Action Plan (Phase II)			x	
Action Plan for the Reduction of Absolute Poverty (PARPA II)	x	x	x	x
Master Plan for Disaster Risk Reduction (PDRRD)			x	x
Urban Master Plan of Maputo Municipality	x		x	
Maputo's Resettlement Policy Framework	x	x	x	
PROMAPUTO MMDP I and II	x		x	

4.3 Interviews

Codes were extracted from the transcribed interview data which then subsequently led to the formation of a variety of themes. Codes were developed when participants repeated words or phrases often, when something arose in discussion that was surprising, when the participant mentioned experiences or understandings similar or conflicting with reviewed

Figure 14: Wordcloud of most repeated words during interviews.



literature. Figure 15 (above) presents some coded words that were repeated often by multiple participants.

Six main themes were derived from the interview data that were of high relevance to the project: the importance of culture in informal settlements, the role of planning in climate adaptation, the access and utilisation of climate data, governmental trust, urban expansion in Maputo and capacity building (Table 4). The table highlights the main themes created from the data, accompanied by some key quotes. Codes were also added to additional themes that were not included in this analysis. A larger coding table can be found in Appendix 7.

Table 4: Codes, themes and example quotes from interview analyses.

Themes	Codes	Examples
Importance of culture	• Don't want to leave their homes • Urban planners should understand the culture of people • Good social networks • What makes them return?	"Business is the chief reason they always come back" "Things can get worse, people are starting to leave their houses because people cannot cope anymore" "For them, living close to the town is a business opportunity."
Role of planning	• Look at other cities • Very important for climate adaptation • Enemies of progress	"You shouldn't just be planning on what is happening in your city but around the world. Bangladesh, Cologne, Durban. How can we integrate some of these strategies into our own planning?" "I'm definitely seeing increasing awareness of climate change in general, which is good... Beyond that, I think it does take a concerted effort. Urban planning course - can we integrate climate change into that - this is what climate risk is going to look like in places where you're gonna be working"
Access and utilisation of data	• Radio bulletin • Planners need to trust the data • Information needs to be credible • How to use climate data	"We have better information available, but we need to make sure we get it to the right people in a format they understand so that they're able to use it and know how they can use it to make their decisions differently. That's as true for urban planners as it is for farmers and fishermen and women." "There must be something between the planning and the execution. I don't know what is failing there."
Trust	• Relocation for political gain • (Policy) documents not evident in real life • Prevention and penalties	"People must realise if they follow the urban master plan these issues should have been avoided." "Mozambique has a long history of trying to resettle people in order to suit elections."
Informal settlement expansion	• Selling a problem • Giving power to people on precarious land • No planning in advance • The 70s and 70s saw a mass exodus of people coming to Maputo	"The biggest growth in terms of informal settlements was experienced in the 80s and 90s because we had a civil war in the rural area." "Once the coconut plantations were affected by disease, then people migrated to Maputo, where they overcrowded informal settlements." "They are selling a problem for a new person and in the flooding season that person will be facing the problem." "They definitely don't have good drainage. I mean, when you drive around Mozambique, you realise that water and sanitation and hygiene is a big issue. Obviously no waste disposal. So I think that's a big risk for kind of disease.:
Capacity building	• Capacity building for individuals • Capacity building for institutions • Radios for communities, powered by solar • What climate change impacts do we want to prevent? • Prevention rather than penalties • Cross-collaboration within government • FRACTAL Impact Project	"There must be something between the planning and the execution. I don't know what is failing there." "We need houses that can withstand environmental pressures." "We should be encouraging prevention, not enforcing penalties" "Cross-collaboration within governments is vital to any climate change adaptation"

5. Analysis and discussion

This chapter will present an analysis and discussion of the key ideas formed in interviews, noteworthy observations from local and national policies, in conjunction with the mapped data illustrating urban change in Maputo. Firstly, discussion will be focussed on urban change in Mozambique's capital, where the insights drawn from interviews will be salient. This chapter will then explore barriers to communicating climate change risk to urban planners and the implications involved to increase the adaptive capacity of the city. Finally, the discussion will identify and discuss some mechanisms highlighted by research participants that might help to overcome these barriers.

5.1 Urban change in Maputo

One participant explained how, while Maputo's population has been growing over the past five decades, the biggest increase in informal settlement residents was seen in the 80s and 90s, as many people from the north of the country were fleeing the devastating impacts of the ongoing war: *"It was like a mass exodus of people coming into the city to seek shelter and livelihoods. Most of them had previously depended on agricultural practices in the areas that were affected… Because of the war, authorities also did not have enough power to enforce any measurement in terms of planning."*

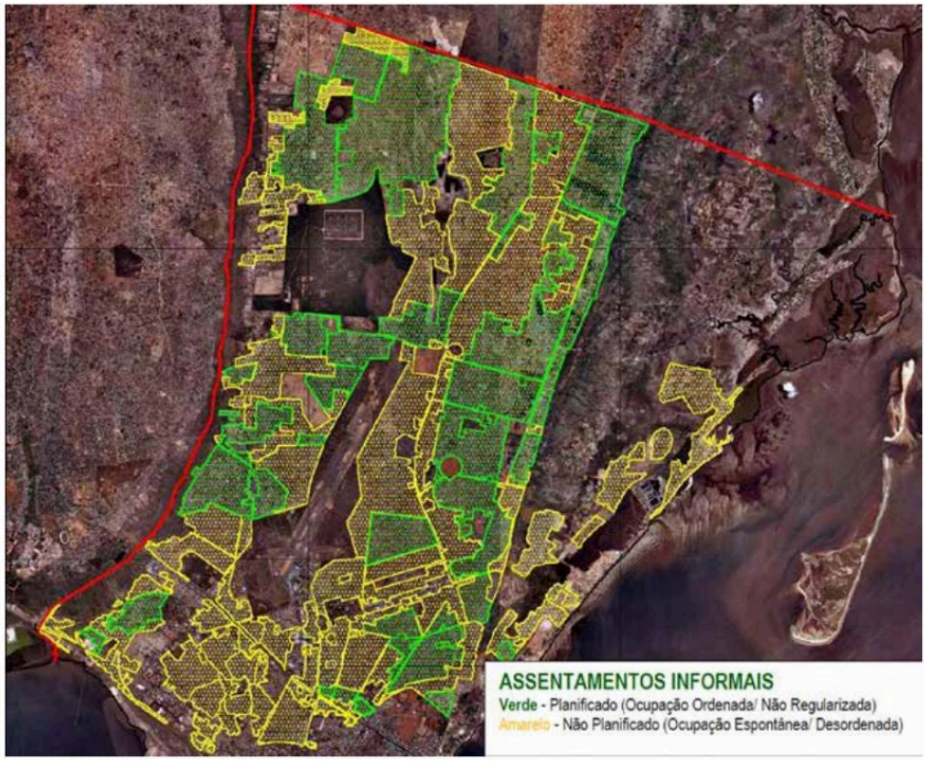


Figure 15: Informal settlements in Maputo Municipality. Source: MMC - ProMaputo Phase II Program 2014, in MMC, 2016)

The mapping exercise illustrates how urban developments across the city are not uniform. While the cement city experienced urbanisation to a high degree, developments in the urban periphery and coastal areas also gradually accumulated over time. However, arguably this data is better understood when coupled with population data, which illustrates an increase in over 100,000 residents between 1997 and 2007 (Appendix 8), meanwhile Figure 13 only shows a minimal increase in built-up surface area during this time. Also, while this mapped urban expansion does not shed light on the expansion of informal settlements *per se,* combining this method with analysis from interviews can reveal other interesting insights. One participant stated that informal areas had been mapped for Maputo (Figure 16) however expressed that *"this was a good starting point, but now action is required".* Figure 16 shows formal areas (in green) in comparison to informal areas (yellow) and their prevalence across the city. Data on informal settlements is scarce in Mozambique, and is often limited to the quantitative measurement of access to basic services such as water and electricity (Croese, et al. 2021). Moreover, one participant raised the problems with a lack of structure: *"there is just no structure to these places, sometimes you might have to walk through someone else's living space to get to where you need to be, whether that's another house or the street".* This corresponds with research trying to understand development patterns of informal settlements in Nairobi, Kenya, as Ono and Kidokoro (2020:83) who present that "spatial characteristics and conditions within informal settlements are not uniform."

When discussing motivations for moving to Maputo, participants also explained that some upgrading in informal settlements had led to more people accumulating in the area. Initiatives such as connecting houses to water and power systems *"encouraged people to live there"* in spite of whether the area was high-risk or not. The participant explained *"why would people think it is unsafe if they were connected to the town's power supply? It just doesn't give the right message."*

5.1.2 The natural environment

Figure 13 illustrates how areas of the coastal zone have been somewhat urbanised. While not as intensive as other areas of the city, interview participants raised this as a problem. Participants frequently referred to the natural environmental and often expressed concern at the decrease in natural spaces across the city, particularly the loss of mangroves and forested areas.

One participant explained that *"we are losing our natural spaces that can help our protection from climate change".* They explained that mangrove loss has been apparent since 2000 and has "*increased incidences of flooding. People will move into mangrove areas, cut down the mangroves and use the sticks to construct their houses."* While not attributing mangrove decline entirely to informal settlement residents, another participant linked the loss of

mangroves to the increased vulnerability of the city, stating that *"the mangroves are nearly completely gone. Waves will reach the coast with the same intensity but the power is not absorbed by the mangroves anymore".*

Natural habitats such as coastal wetlands, including mangroves, saltmarshes, seagrass meadows amongst others are recognised for enhancing protection against climate change impacts. The coastal zone of any area is continually transformed by energy from waves, tides, runoff, and groundwater discharges (Silva, et al. 2020), however mangroves in particular provide good storm protection for coastal areas as their roots break up energy during a storm surge (Moolna, 2019). As Maputo is subjected to storms often, one participant acknowledged that the city had joined the Cities with Nature project, an initiative aiming to integrate biodiversity and nature into urban planning activities. While engagement data is absent for Maputo, the project provides extensive resources on how the built environment can incorporate natural areas and subsequently contribute to disaster risk reduction in the city (Cities with Nature, 2022).

5.2 The role of urban planning in climate adaptation

While literature presents that climate issues often have a low impact on urban planning processes (Eliasson, 2000), interview participants were all consistent on the importance of the role of planning in reducing climate risk for informal settlement residents.

In January this year, the chairperson for the INGC, Luisa Meque, praised the level of readiness of the teams set up to act in the event of flooding in the Chokwe district in Gaza Province (Mozambique News Agency, 2022). Meque confirmed the high level of interventions taken by the Gava provincial government, however the author then depicts how the MMC is still failing to provide a decent drainage system for communities, leaving the same low lying neighbourhoods consistently flooded. This is consistent with a statement from a participant based in the city who explained:

"*there is evidence of constant flooding for the same people over and over… There are areas in the centre of the city that can flood all year round, even during droughts. It's constant for those people."*

National and municipal policies analysed recognised that weak planning legislation allowed for the development of unplanned informal settlements. As such, a specific priority of the PARP II is to integrate climate change risks into provincial planning across the country. The ENAMMC also presents that the integration of climate aspects into urban planning will allow cities to adapt to current and future climate impacts, emphasising its importance.

However, this is a significant feat when considering the extent to which climate change should be integrated. In a graphic modified from Satterthwaite (2008), Fallmand and Emeis (2020) present the wealth of factors to be considered in a sustainable city. Resilience to coastal hazards in Maputo is only a small part of the city's development, particularly as Maputo has other developmental needs on the agenda. As 70% of the urban population live in informal settlements and are already vulnerable to climate change impacts, arguably it would be an important first step to address these vulnerabilities first.

Figure 16: Urban issues towards sustainability and their interrelations. Source: Fallman and Emeis (2020, adapted from Satterthwaite, 2008)

5.3 Barriers to communicating climate risk

During interviews, before progressing to questions regarding climate data for urban planners in Maputo, half of the participants had already highlighted challenges when answering other questions about risks to informal settlements and government intervention in informal settlements. Some participants expressed disappointment that urban planners did not seem to be doing more to integrate climate risk or any adaptation measures into the city, and presented the following as barriers to the use of information: a lack of data, lack of access to data, and inability to utilise data.

5.3.1 Lack of data

Participants were asked what barriers urban planners might face in accessing localised weather and climate projection data. Answers were highly disparate, with some participants explaining that *"they must have the data*" and *"they can get data from the INAM"* to inform their work, while others were less optimistic, explaining that *"data is often hard to reach, even if you work within government. There are significant gaps in the data, and this is not just evident in Mozambique but true across African countries."* The availability of data across Africa is a frequently spotlighted issue, particularly after destructive natural hazards. Articles have referenced a lack of government funding, technology, weather stations, and staff capacity as causing the data gap (Chason and Ombuor, 2021). However, the INAM frequently shares weather data with the nation and INGC has conducted extensive studies on the impacts of climate change on the whole country (research participant, 2022), with one participant claiming "*the data is there if [urban planners] go looking for it"* however another explained they heard people were requesting money for this data.

Participants also raised the lack of data on informal settlements as a barrier to implementing climate risk in urban planning. Data on informal settlements is not sufficient, which is owed to past discriminatory views on informal settlement residents (Satterthwaite, et al. 2020). However, research has demonstrated the importance of giving agency to local community members through the process of mapping their community. To elaborate, Fallman and Emeis (2020) says the process of community mapping allows them to share information within the community as well as collect information to generate further knowledge on the communities' greatest needs and vulnerabilities. Urban communities across the world are collecting standardised community data through the Know Your City campaign as a means to communicate the "scale and extent of informality and deprivation in the spaces they occupy" (IIED, 2014:1). The aim is for residents to collect data on size, tenure status, basic amenities, and access to health, social and transport services, then data is computerised (SDI, 2015). This would be a beneficial exercise for decision-makers, as often local governments have no records of those living informally, meaning that their history and profiles are largely unknown (Patel, et al. 2012).

Leveraging community data carries high importance; Patel, et al. (2012) present the ways in which encouraging participatory surveys with informal settlement residents can improve understanding of the local area. The authors present four methods of obtaining data, firstly including enumeration whereby residents survey and map themselves, secondly settlement profiles to map the land they occupy and relocation history and circumstance, thirdly household surveys to allow for a deeper understanding of the culture of informal settlements, and finally vacant land surveys, which could highlight suitable land in the city for those in high-risk areas and vulnerable to SLR. Furthermore, in engaging with women in informal settlements, it allows for representation of the most vulnerable in informal settlements and a greater understanding of the challenges that women face in informal settlements and understand how their lives are implicated by climate risk (Patel, 2021).

5.3.2 Lack of access to data

After discussing whether data existed or not, participants then presented issues surrounding data accessibility. One participant explained:

"You can receive information as a normal citizen by television, by work, by radios, by WhatsApp. If you are an urban planner, you are in the architecture and urban planning WhatsApp information group, which has information related to those professionals circulated there. If you are not a member of this group, you are just going to have the information like other citizens."

Another participant explained how data could be *"be sat within the city government but not accessible due to a serious lack of communication between departments".* The participant elaborated that climate change is a cross-cutting problem that one singular governmental or municipal department alone cannot solve. UN-Habitat (2019) has acknowledged that municipalities across Mozambique lack capacity, caused by the remuneration chasm between the public and private sector. Currently, and not specifically to Mozambique, African climate data is held disjointly by various agencies and is uncoordinated and inaccessible (Taylor et al, 2021). The need for cross-collaborative governance in aiding communication on climate risk will be considered later in this discussion.

5.3.4 Inability to utilise data

Some participants expressed concern at the lack of knowledge on climate risk presented by key decision-makers in the city. Two participants stated that some "*do not know the difference between climate and the weather",* with one participant further explaining that decisions made in the city for land-use planning and developments are *"often not based on actual scientific data".* This coincides with research highlighting that institutions do not use climate information in practice for decision-making in African cities (ICLEI, C40, 2018); one participant claimed that *"some judgements and actions are purely based on gut-instinct".*

One participant presented another barrier that *"when cities have researchers come in to gather evidence, they don't want to read a hundred-page report, they don't know how to handle research papers. Instead a summary would be so much more worthwhile to ensure their decisions are based on scientific data".* Therefore, highlighting that quantity and readability of climate risk is extremely important for data utilisation.

Previous literature has demonstrated that climate data faces challenges in its communication to all groups who need it as different industries require data that is applicable for their realm of work. For example, farmers might be interested in when it is expected to rain, for how long

and if this is projected to be the same year on year (Vincent and Conway, 2021). Therefore, rather than climate communication including statements of how nations are going to experience change in their climates, the usability gap needs addressing so that people can understand the various knock on effects this is going to have in their remit.

Another matter that compromises ability to utilise climate data is handling uncertainty in climate modelling. Uncertainties prevail in all climate modelling as scientists cannot accurately project the scale of hazards or provide accurate evolution rates as the climate continues to change (Ocean and Climate Platform, 2021). Particularly for SLR, there is a "large and deep uncertainty about the magnitude and timing of SLR beyond 2050" which challenges decision-making (Oppenheimer, et al., 2019:399). However, in an assessment of utilisation of climate data for decision-makers in Latin America, Ryan and Bustos (2019) suggest that decision-makers, including urban planners, should plan for hazards with high-end impacts regardless, such as the potential damage of a future storm or the highest projected level of SLR. The authors argue that adaptation must be ambitious, and as urban planning has a significant role in adaptation, this could foresee planners addressing land use in the city in ways that fall outside of expected impacts.

5.3.5 Trust

The theme of trust repeatedly appeared during interviews with participants presenting multiple reasons why trust, or a lack thereof, in the municipal council is hindering progress to improving informal settlements and adapting to climate change.

One interview participant raised the issue of fear of losing their house for many informal settlement residents, during coastal hazards and to future development in the city. This corresponds with Andersen and Jenkins (2011) who suggest that it is much easier for private companies in Maputo to dominate land that might once have been preferable for informal settlements. In fact, as fewer sites become available for development in the city, informal areas in the urban periphery are under pressure from this need for land (Andersen and Jenkins, 2011).

Another participant expressed a lack of trust in adequate enforcement in Maputo: "*Any country that is reasonably organised should be able to have a plan and enforce it... There is evidence of constant flooding, constant lack of sanitation…".* For Maputo, there is a clear disconnect between policy and its implementation. Participants raised the Maputo Urban Master Plan: *"[Decision-makers] must realise that if they follow the Urban Master Plan then these issues should be avoided. The plan is important but it needs to work. The municipality should know which areas are suitable for living, for industry… I guess there are documents there, but you cannot tell from what you see in real life."*

These statements correspond with Berrisford (2014:181) who states that it is "too easy for researchers, officials and citizens to conclude that better legislation, or even better implementation of legislation, will solve the African urban crisis". However, the ICLEI (2019b) promote the need to eliminate discriminatory policies and attitudes to ensure that the needs of informal settlement residents are managed in urban planning for a resilient city. In reviewing policies and strategies for climate change adaptation and urban development, where informal settlements were mentioned, they were not talked about discriminately or negatively, but represented as a vulnerable group who would benefit from intervention.

One research participant raised trust as a significant barrier to community engagement with resettlement programmes because of the bad track record left from previous programmes, having consequences for future urban planning initiatives. In Mozambique, resettlement is "embedded in a complex historical legacy of government interventions in floodplains" (Arnall, et al. 2013:18). It has a long history of resettlement, dating back to Portugal's colonial rule, the legacy of which has enabled recent governments to reinvent resettlement (Arnall, 2016). For example, O'Laughlin states the Portuguese authorities commonly resettled farmers into villages that were easier to organise for forced labour and tax-raising purposes (2002, in Arnell 2016). Governments have used the facade of reducing community exposure to hazards through forced eviction for political or economic gain (Barnett and Webber, 2009, in Arnall, et al. 2013). Interview participants raised that it was common for informal settlements to be relocated or resettled elsewhere in the city.

Meanwhile, research with residents of Maxaquene A, a *bairro* in Maputo, expressed that if a person had been relocated four times due to floods, this area should now be zoned as unsafe and the community should be resettled (Zehra, et al. 2019). Moreover, one research participant in this study highlighted that the 2020 Disaster Risk Reduction (DRR) Law places responsibility on individuals to not settle in high risk areas, or else face a penalty. Table 3 highlights that the 2020 DRR Law presents informal settlement residents as a source of problems. While subjective, this box was ticked for the criminalisation and penalties forced on individuals for settling on high risk areas. However, one participant expressed concern at the lack of enforcement in encouraging people not to settle in precarious areas: *"People who live in mangrove areas here in Maputo have been advised not to do so, and whenever there is a flood or a storm, they are forced to move… if their house is destroyed or flooded, they are provided with new plots and assisted with building new houses. Yet they abandon these and go back to the same areas which are vulnerable. They often even sell the plot they were given."* Another participant explained that this is simply "*creating a problem for a new household".*

Meanwhile, one participant claimed that *"there is a need to make sure that instead of reinforcing the penalties, we should reinforce the prevention."* Arguably, people searching for somewhere to live will not consider or perhaps understand the environmental risks

associated with their chosen location. Preventing people from constructing houses in high-risk areas is an important first step, however interview participants expressed this was not an inclusive measure. Therefore, a lack of trust in successful and beneficial government intervention is likely to inhibit adaptation planning and present barriers to future urban planning work for increasing climate resilience.

5.3.6 Implications for adaptation to SLR

As trust in government interventions in informal settlements is arguably weak, this could have serious implications for planning for adaptation to SLR in Maputo. Participants were asked about alternatives to resettlement when considering the threat of SLR. Maputo's SLR projection (Figure 8) shows how much of the coastal zone is projected to be consumed by SLR. This means that informal settlements within the city could then be on the new coastline and therefore creating new serious challenges. However, interview participants state that because *"impacts are not yet visible"* and there are more urgent needs, it is simple to comprehend that this is not an immediate concern for city officials. While the atmosphere reacts quickly to changes in GHG levels, SLR is a slow onset hazard with little perception of immediate risk, subsequently causing a lack of motivation from communities to move from their location (Kloos and Baumert, 2014; Met Office, 2017). This is also recognised in an IPCC report, whereby the long-term commitment to SLR and the deep uncertainties surrounding the magnitude and timings of saltwater inundation past 2050 is challenging (Oppenheimer, et al. 2019). This, arguably, combined with the understanding that informal settlement residents have other, more immediate concerns to address, understandably pushes SLR out of scope for immediate challenges that need addressing. Interview participants displayed contested answers surrounding SLR and the urgency for action. Previously, the occurrence of disasters influenced action for informal settlement management, whereas anticipatory resettlement is less common.

While the policies analysed in this project vary in strategic objectives, there is a clear legislative commitment from Mozambique and MMC to increase resilience to coastal hazards and a recognition that poverty and increased, unplanned urbanisation increases vulnerability to climate risks. Figure 17 highlights how four competing agendas are overlapping in an aim to reduce local risk.

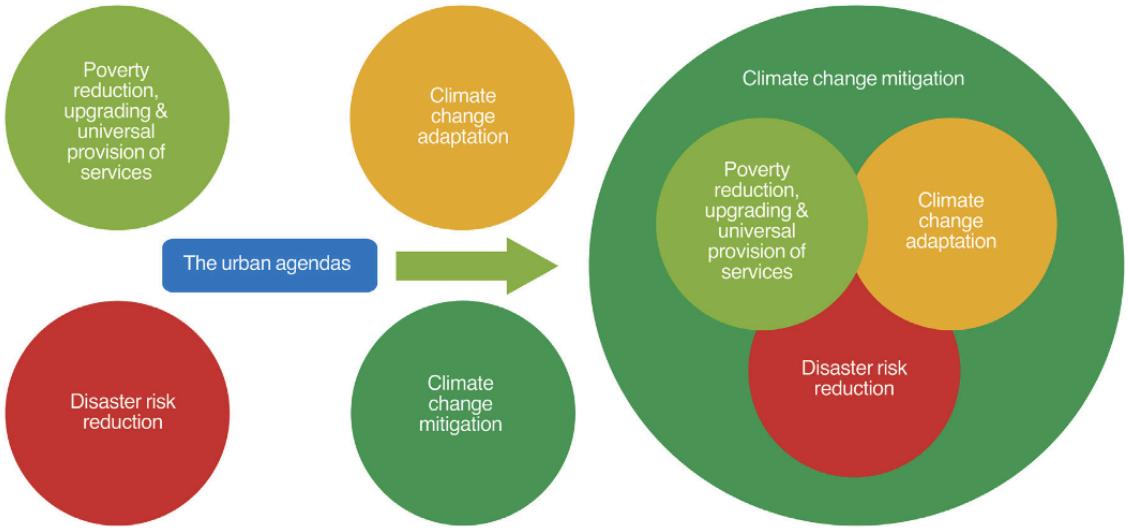


Figure 17: Competing agendas transformed to an integrated response to climate change. Source: Bartlett and Satterthwaite, 2016, in Satterthwaite, et al. 2020.

In considering an integrated approach to increasing urban resilience, PARPA II stood out as inclusive of discourse surrounding pre-existing vulnerabilities exacerbating climate risks and the need to develop integrated measures. This coincides with the sentiment of one research participant who, when asked what might increase informal settlement residents' resilience, explained:

"I think you can take two approaches to this. One is probably the one which is taken most often, a kind of plaster approach to the situation. The other one is the more sort of fundamental, structured approach which looks at what creates situations where we have people in informal settlements in the first place and how we can address that."

As such, this section has demonstrated how a lack of trust in governmental action that could increase informal settlement residents' resilience to climate change could be considered a significant barrier to communicating risk and planning for adaptation in the city. This could have extensive implications in planning for future SLR.

5.4 Mechanisms to close the data gap(s)

Participants shared ideas of how to better communicate climate risk and enable urban planners to adopt risk into their work.

5.4.1 Training

The IPCC report asserts that there is a general lack of training and knowledge on recent and projected trends in SLR, comprising the use of data in decision-making (Oppenheimer, et al. 2019). Interview participants who suggested training as an option for mitigating issues around communicating climate change information for adaptation and planning mentioned two modes: educational courses for prospective planners and team training for existing planners. Maputo's Eduardo Mondlane University hosts a Masters degree programme: *Planeamento e Gestão de Assentamentos Informais* (Planning and the Management of Informal Settlements). The course trains professionals to analyse landscape transformation processes, engage with tools for intervention in informal settlements, produce and disseminate knowledge on informal settlements, and to engage in interdisciplinary dialogue and cooperation for urban landscape management (Eduardo Mondlane University, 2012).

Moreover, the 2017-2030 PDRRD outlines the need for training programmes for all involved in disaster risk management, with a particular focus on the impact of gender and social inequalities in further impacting risk. This plan therefore recognises there are vulnerabilities that are compounded by disasters. The training program is stated to include government members, private sector actors, organisational partners and civil society. More specifically, the PDRRD also seeks to establish a training program in territorial planning with disaster risk reduction criteria, however this does not go beyond stating that applying rules and regulations should be based on assessments of exposure, hazards, threats and vulnerabilities to disasters.

When discussing team training for existing planners, one research participant explained that *"training [on climate risk] won't work"*. They instead explained that urban planners need to understand the culture within informal settlements before conducting any risk analyses of the areas. This will be considered further in section 5.4.3 of this paper. However, others were more optimistic of trainings, as one participant stated that *"seminars, webinars, any form of learning platform can make them aware of what is going on".*

However, one method of training that three participants pushed for was for understanding risk and risk perception.

5.4.2 Standardising risk perception

Government institutions tend to identify damage to property and loss of life in the event of a natural disaster, relying on technical information to justify their perception of risk, whereas individuals might fear the loss of the safety and security of their homes, social networks, and their livelihoods (Johnson et al. 2021). As such, risks are often perceived differently and this perception can lead to different outcomes.

Participants raised the value of risk mapping as an exercise for urban planners in order for them to fully understand the risks presented to various communities. For example, one participant explains that planners need to *"firstly understand risk in order to incorporate it in their planning codes'',* while another clearly stated the need of training on standardising risk in urban planning teams. Between a team of individuals, many will have had varying life experiences that will predetermine their perceptions of multiple risks, including risk presented from climate change. Risk perception is highly context-specific and varies between individuals, having an influence on a community's exposure and vulnerability to climate change impacts (Oppenheimer, et al. 2019). As such, Johnson et al. (2021) present that the education and communication of different perceptions of risk should be an integral part of adaptation planning, however this is something the authors note is rarely applied in practice. Risk-mitigating actions, such as resettlement, often overlook factors such as the loss of livelihoods, physiological and social consequences and disruption to social networks (Lwasa, et al. 2021).

5.4.3 Understanding the importance of culture

'Culture' was repeated frequently during interviews, as participants explained that a greater understanding of *"what circumstances create a situation where we have informal settlements in the first place"* coupled with *"motivations or encouragement for them to stay"* is integral in improving urban resilience.

Firstly, there are many reasons why people seek to remain in high-risk areas such as floodplains, in the foothills of volcanoes, within areas at risk of wildfires or landslides, or in coastal areas prone to erosion. Interview design did not include questions about the culture of informal settlements or the motivations they might experience to stay there. Interestingly, participants raised the importance of this. One participant explained that *"they have their livelihoods at that place".* With public infrastructure arguably weak and fragmented across the city, access to the centre of Maputo is restricted and easier to access if people are close-by.

Participants explained that informal settlement residents are also a part of the city's informal economy: "*business is the chief reason* [for returning to informal settlements after relocation or resettlement]. *The only thing they know is to sell in the street. So they will try to secure housing close to the centre of the city…It's just for survival. There is nothing that would attract them to go far from* [the city centre]. Moreover, the value of social networks within informal settlements was a repeated motivation recognised by research participants. While informal settlements have previously been perceived as disorganised and lacking social cohesion, this research and indeed other articles have shown that positive social relations persist (Morgner, et al. 2020). A study investigating quality of life in informal settlements in three locations in South Africa presented social connectivity as a significant contribution to life satisfaction

(Richards, 2007). The author found that informal settlement residents were positive about having good family ties, friends, and feeling cared for by the community.

Luxeria de Hulene

In 2018, seventeen people were killed when heavy rains caused a landslide at Hulene rubbish dump in Maputo (Swingler, 2018). Three research participants raised the incident at Hulene, talking of the *"tragic disaster in which many people needlessly lost their lives".* Participants explained that the dump provides *"local people with a way of making money through waste-picking"* which is why the periphery of the dump is heavily occupied by informal settlements. Families were resettled away from the rubbish dump (Club of Mozambique, 2018), however research participants explained that many residents were reportedly unhappy with the government's resettlement programme due to significant lack of power, compensation and transport infrastructure at the new location. Now, the dump is set to be closed by the local government. This has been faced with backlash from local residents who depend on the dump for their survival, many of whom are women (Africa News, 2022). For those that were resettled from Luxeira de Hulene, some have returned to continue with litter-picking, as perhaps their perception of risk was greater when faced with a lack of income opportunity in a new, low-risk area. Differences in risk perception has also been highlighted elsewhere in the city. Zerha et al. (2019) worked in Maxaquene A, where residents expressed a lack of comfort with being evacuated due to a fear of crime. The authors write that during the 2000 floods, only children and young family members were evacuated while adults remained to protect their homes and belongings.

The importance of understanding the individuality of informal settlements and the cultures within them cannot be understated here. Understanding why people have settled in a location in the first instance, along with understanding what makes people stay in the face of a disaster is integral. Arguably, identifying the priorities of households and wider communities is the first step in the process of identifying how to improve their adaptive capacity, by including their priorities and values from the start. Choice experiments were conducted with informal settlement communities in Alexandria, Egypt, allowing participants to express preferences for alternative settlements due to the risks of coastal erosion and SLR. Participants in Kloos and Baumert's (2014) study expressed that transparency of the entire resettlement process is imperative to their will to leave the existing neighbourhood. Other factors that strongly influenced willingness to leave include public and social infrastructure to a good standard, the degree of financial compensation, promised income and job security with preference to continue in their current profession, as well as the continuation of existing social networks. While this concurs with expectations of successful resettlement and includes elements of social justice, the authors highlighted that the no-resettlement option was more desired for 40% of participants, alluding that alternative options were so undesirable that residents would rather persevere in an at-risk area. This study is significant in contributing to

resilience building for informal settlement residents, highlighting the importance of the attributes of the new settlement as vital to the programme's success.

As 70% of Maputo's population is informal, understanding the individuality of informal settlement communities is vital. For transformative adaptation, a deeper understanding of issues surrounding inequality, justice and identity is integral (Guivarch, et al. 2021). Ensor et al. (2014) suggest that successful adaptation involves techniques that are meaningful in their context, therefore a greater understanding of the cultures within informal settlements is integral here.

5.4.4 Digitising climate data and risk

As previously discussed, many participants explained that urban planners and other professionals get data from the INAM via WhatsApp, a mobile application. One idea to better integrate climate and weather data into urban planners' work is to either (i) add it to a pre-existing web platform that urban planners frequently use or (ii) create a shared digital space for professionals to share information about all aspects of climate data, as well as projects taking place in informal settlements. One participant recommended that a "*forum of experts*" would help to inform urban planners' and other professions' understanding of climate risk and adaptation planning. This could also include maps highlighting vulnerable areas, as interviews highlighted the importance of knowing where vulnerable areas are, particularly to SLR, and encouraging urban planners to consider safer land within the city that could instead be used for affordable housing.

Arguably, if urban planners better understood the implications of climate change for their city and what this means for their work, this can reduce the data usability gap. The participant mentioned a forum or website could include a range of professions including urban planners, non-governmental organisations, ICLEI practitioners, architects, and water resource managers. If individuals can understand local climate risk and how this implicates the city, this could allow for the integration of climate risk into more realms of work in the city (Satterthwaite, et al. 2018). Digitising climate data could also reduce barriers to collaborative governance that interview participants also highlighted as a significant issue, not just to accessing or disseminating climate data.

5.4.5 Building capacity

5.4.5.1 Engaging with informal settlement residents

In discussing issues with a lack of collaboration in African city governments, one participant mentioned ICLEI's Impact Project (2018-2020) which sought to improve planning in cities in Zimbabwe and Malawi to create a resilient future. This project encouraged collaborative governance through the understanding that more voices allows for an increase in the depth

and breadth of knowledge created and shared (ICLEI, 2019a). Moreover, research conducted in informal settlements in Cape Town, South Africa, has emphasised the value of local knowledge in generating information and action for climate adaptation and reducing risk. The Community Resilience in Cape Town (CoReCT) project engaged individuals with local environmental and academic knowledge in order to create insights from lived experiences in these areas (Ziervogel, et al. 2020).

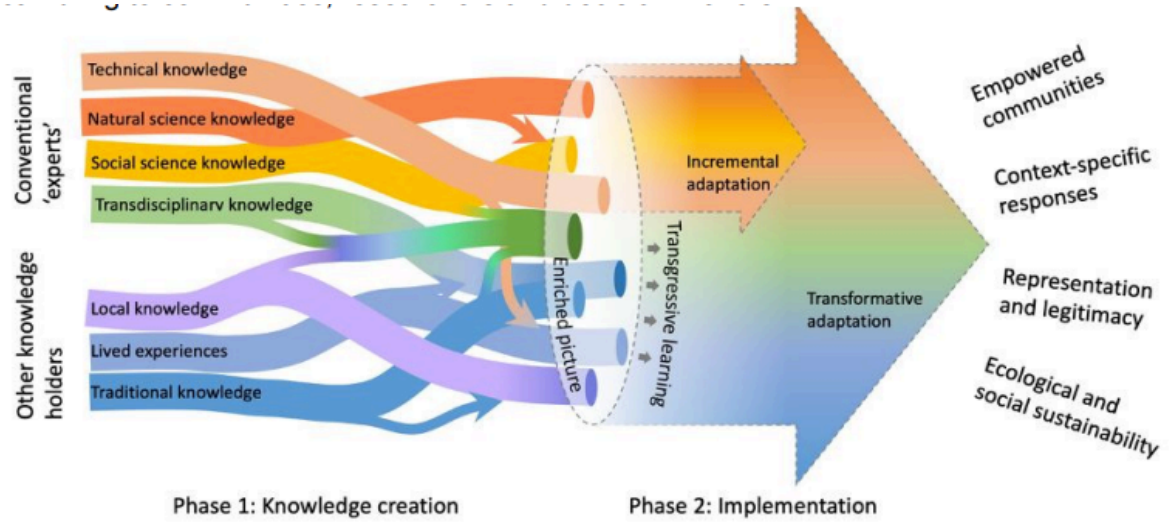


Figure 18: Capacity building for adaptive transformative adaptation. Source: Ziervogel, et al. (2020 adapted from Tengö et al 2014).

Knowledge generation is an important process that requires a transdisciplinary approach which is often not found in top-town transfers of knowledge (Ziervogel, et al. 2020). This, the authors argue, can result in positive outcomes including community empowerment, reciprocal learning and confronting inequalities. Urban planners have a role in knowledge generation and subsequent utilisation of this knowledge. As such, urban planners should work closely with informal settlement residents to gain their experiences of living in informal settlements, the difficulties they experience during a coastal hazard and its aftermath and their understanding of future climate change impacts.

The co-production of knowledge in this way is integral to creating data that is usable for planning and decision-making (Kirchoff, et al. 2015). This is consistent with research in informal settlements in Manila, Nairobi and Cape Town, which highlighted that urban planning for resilience requires more collaborative approaches that cut across the conventional top-down and bottom-up dichotomies (Borie, et al. 2019). However, often knowledge and tools generated from the natural sciences are viewed as more credible and serious, especially when displayed on a map, whereas local knowledge that might be communicated alternatively cannot be easily decontextualised for planning purposes (Borie, et al. 2019). However, arguably the importance of knowledge co-production with local residents cannot be overstated and is a worthwhile contribution to planners.

Fremilo exercises top-down governance across Maputo, especially through *chefes de quarteiroes,* who are "acting as a break on community voices entering decision making" (Ensor, et al. 2014:30). Informal settlement residents lack access to ways in which they can hold local governments accountable and therefore suffer political exclusion (Moser and Satterthwaite, 2008; Kamete and Lindell, 2010). Informal settlement residents' engagement with the political sphere is therefore important and a key mechanism for communicating climate risk in this way (Ziervogel, 2021). Moreover, informal settlement residents have thorough knowledge and experience of living in these areas, meaning their contributions to their own upgrading or other intervention is paramount. For example, the *bairro* of Chamanculo C was seriously impacted by flooding in 2000 and has since experienced frequent flooding. In a paper discussing options for the residents, residents had agreed on the clearing and cleaning of drainage for sufficient wastewater and rain/storm water flow, restoration of a drainage ditch, education of residents about the impact of throwing waste into waterways and water infrastructure. Moreover, the group also proposed construction of new major drains and the levelling of streets, and that includes if some families might have to leave their property. This was seen as a priority action over simply moving residents in low-lying areas of the *Quarteirâo* to outside of the *Bairro*, as residents expressed their disapproval of this action at a plenary meeting (UCL, 2013).

While no participants identified women as experiencing additional vulnerabilities in informal settlements, research highlights the importance of this. Inviting women to engage in local governance and share experiences of living in informal settlements is also extremely valuable. For women living in informal settlements, pushing for stronger representation not only invites empowerment, but paves the way for more sustainable settlements that are inclusive of the most vulnerable (Cities Alliance, 2017). The national Climate Change and Gender Action Plan (2014) focuses heavily on making a case for gender equality across Mozambique, and explains the importance of addressing gender divisions in DRR, enabling women to access climate information and create a space where they can share their knowledge on their local environment.

5.4.5.2 Cross-collaborative governance

The 2008 Urban Master Plan of Maputo includes that the INGC had asserted influence on the Ministry of Environment to assume overall responsibility for climate change. Meanwhile, the 2020 DRM Law stresses for each provincial government to adopt measures to publicise the creation of residential, industrial and commercial zones due to the threat of SLR. Both exercises require a collaboration between and within municipal departments in MMC.

Priorities within a city are often shared between governmental departments, organisations and communities. However, a lack of collaboration considerably limits the extent to which a shared voice can develop and effectively create change. Moreover, one research participant

stressed the value of integration, explaining that *"planners need to consult other stakeholders and people in government but there is no integration between them… others need to see urban planners as holding a key role, but this is currently lacking"*. ICLEI's Impact Project (ICLEI-Africa, 2021) identifies key drivers for collaboration, recognising that multiple levels of government are mutually dependent on each other for implementing climate change and disaster risk reduction policies:

- Government legislation
- Political will
- Good resource provision and capacity to act.
- Representation

MMC is continuing to working to develop a collaborative governance structure. ProMaputo I and II aimed to strengthen the city's financial opportunities to engage in more development projects for the city, as well as improve city infrastructure such as roads, drainage systems and coastal protection (ICLEI-Africa, 2012). Decentralisation of power in Mozambique has attributed more power to MMC, however the local government is recognised for lacking capacity and resources to deliver any promised services to the urban poor, of whom are found in informal settlements (Castàn Broto, et al. 2013). Disaster risk remains a persistent risk to Maputo, however the national PDRRD (2017-2030) aims to integrate DRR into all governance levels, including decentralised powers. The document addresses a number of the issues shared by interview participants, as highlighted in Figure 19, however arguably needs considerably revision for Maputo. Currently, the UNDP (2021) is supporting Mozambique to undertake reforms that will result in inclusivity within decentralised powers, particularly enabling the strengthening of mandates that support economic opportunities for women, youth and vulnerable populations.

Figure 19 (above): Priorities from the Master Plan for Disaster Risk Reduction (2017-2030) with insights from interviews.

ICLEI-Africa (2012) state that MMC is willing to adapt to climate change, however it now needs to rely on the integration of government officials, practitioners, academics, those in the private sector alongside urban planners to work together to enable a climate resilient Maputo.

6. Conclusion

What are the main challenges associated with communicating climate change risk for adaptation and planning in Maputo, Mozambique?

Urban planning has been recognised as having a key role to play in climate adaptation. This project has presented a number of barriers to communicating climate risk for adaptation planning: the lack of data, a lack of access to data, inability to utilise data and considerable lack of trust in government initiatives. However, interviews with participants shed light on a number of mechanisms that can enhance communication of climate risk, such as training, forums, cross-collaborative governance and workshops.

Research aim: To understand the nature of climate change risks and vulnerabilities in Maputo

Adaptation to climate change presents a significant challenge for Maputo, given the recurrent trend of heavy rainfall and dangerous cyclones (Neves, et al. 2021). Mozambique is highly exposed to climate change impacts, and this, coupled with the variety of climate change impacts the country is subject to contributes to its overall vulnerability. The country is one of the poorest globally and requires significant adaptation efforts to ensure resilient, transformative adaptation for inhabitants. Informal settlements face pre-existing vulnerabilities in Maputo, subjecting them to high levels of risk from coastal hazards.

Research aim: To use remote sensing to map urban change post-independence (1975) in Maputo

Data from the GHSL has been used to map change in urban areas between ten year intervals since Mozambique's independence from Portugal in 1975. Maps illustrated that urban change was most prominent between 1975 and 1995 and was not consistent across the city in more recent years. Maps were complimented by discussion of informal settlement expansion with interview participants, largely attributing concern to the growing lack of natural areas in the city, coupled with motivations for migration to the city.

Research aim: To identify barriers to the use of knowledge for climate adaptation policy and planning for informal settlements and to consider what tools and mechanisms can help to overcome these barriers

This project has identified a number of barriers that limit communicating climate risk to urban planners in particular: lack of data, lack of access to data, and inability to utilise data. However, interviews with participants shed light on a number of mechanisms that can enhance communication of climate risk, such as training, forums, standardising risk perception in urban planning, cross-collaborative governance, workshops, or creating a digital space for relevant data.

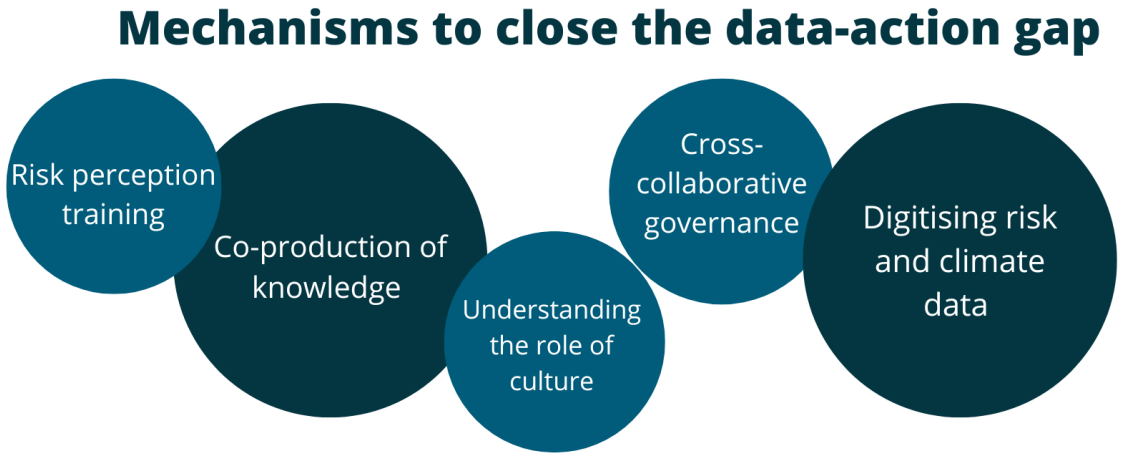


Figure 20: Mechanisms identified in this study that could help to close the data-action gap

6.1 Policy Implications

This study has emphasised the significant role urban planning can have in climate adaptation for Maputo. It has highlighted the individuality of informal settlements and the unique approach that is required to build the resilience of these communities in the face of various coastal hazards.

This project has highlighted that while SLR is set to be a significant issue for Maputo, informal settlement residents and the realm of urban planning have other, more pressing issues to face rather than a hazard that is not yet overtly visible. This project can therefore prompt future discussion on when a suitable time is to address SLR for the city. Moreover, this discussion has also analysed the role of resettlement in this approach, presenting requirements for successful resettlement in the face of SLR.

This project has illustrated that the co-production of knowledge is extremely valuable in increasing adaptive capacity for informal settlement residents, through strengthening decision-makers' understanding of the vulnerabilities residents face and creating a space for collaborative decision-making. This can enable voices to be integrated into higher-level adaptation measures while legitimising their own knowledge (Ziervogel, et al. 2020).

6.2 Looking forward

This study was limited in that it was entirely desk-based, with no research occurring in Maputo. From here, it would be beneficial to create further discussion with urban planners

and other key governmental figures involved in urban management to generate a greater understanding of their awareness of climate risks in Maputo and what limits their work in enacting on that. Maputo is not the only coastal city within Mozambique with a high proportion of residents living in informal settlements faced with a significant threat of coastal hazards (Table 5). Furthermore, future research could consider ways in which these cities can also increase their adaptive capacity to climate change.

	Maputo	Matola	Beira	Pemba	Xai-Xai	Chibuto	Maniça	Maçia
Population	1,430,000	758,000	620,000	156,000	128,000	61,000	56,000	40,000
Percent of population living in informal settlements	70%	70%	75%	80%	85%	90%	90%	90%
Number of people living in informal settlements	1,001,000	530,600	465,000	124,800	108,800	54,900	50,400	36,000
Susceptibility to flooding	High	High	High	High	Moderate	Low	Low	Low

Table 5: Estimated populations in informal settlements in cities across Mozambique. Source: World Bank (2012)

Following this project, OPALS will be commencing on the south-east African coastline, seeking to increase the accessibility of climate data to urban planners to support transformative adaptation for residents.

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Appendix

Appendix 1 - Low and High SLR Scenarios. Source: INGC, 2009.

Scenario	2030	2060	2100
Low Sea Level Rise Scenario –'best case' (Low SLR)	10cm	20cm	30cm
High Sea Level Rise Scenario- 'worst case' (High SLR)	10cm	100cm	500cm

Appendix 2 - Ethics approval - signature from supervisor

Student: I confirm that I have read and understood the material included in this form and agree to act ethically and in accordance with the requirements set out here.	
Student initials: EW	Date initialled: 01/06/2022
Advisor: I confirm that I have reviewed this 'About your dissertation' page, and any participant information and consent sheets, that I have raised any issues needing correction or clarification, and that any issues have been addressed to my satisfaction.	
Advisor's signature: 	Date signed: 09/06/2022

Appendix 3 - Participant Information Sheet

I am a student at the University of Exeter who is conducting research as part of my studies on the MSc Global Sustainability Solutions programme. Thank you for your interest in taking part in this research project.

Student researcher name: Emily Willoughby, University of Exeter

Project title: Climate adaptation in Maputo, Mozambique: Coastal hazards, informal settlements, and communicating risk

What is the project about?
My research seeks to understand barriers to communicating climate change risk to urban and peri-urban planners in Maputo, Mozambique. Please take time to consider the information carefully and to discuss it with family or friends if you wish, or to ask the researcher questions.

Why am I doing this research?
I am conducting this research and the data will be used as part of my dissertation. The data will be seen by me, those involved in assessing the work and the findings may also be seen by other students as part of the module. I am exploring this topic because I am interested in climate adaptation strategies and communicating climate change.

Why have I been approached?
I have asked you to take part because you have been identified as a key partner in the Oppenheimer Programme in African Landscape Systems programme (OPALS). This project will approach multiple partners for their involvement. Engagement in this project will invite you to an online interview.

What would taking part involve?
I am asking participants to take part in an in-depth interview which will last approximately 30-45 minutes. This can take place in-person or online using MS Teams or Zoom in line with your preference.

I am interested in
- Climate change impacts in Maputo
- The role of urban and peri-urban planners in climate adaptation and reducing vulnerability
- Barriers to communicating climate change to urban and peri-urban planners
- Methods of increasing informal settlement residents' resilience to climate risks and coastal hazards

Se em algum momento da entrevista você desejar dar respostas mais completas em português, fique à vontade para fazê-lo. Estes serão traduzidos com o apoio do meu orientador de dissertação que é falante nativo.

What happens with what I say?
Anything you say will be kept anonymous (your name will not be used). All participants will be given pseudonyms, and it will not be possible to identify individuals in the research.

If you give consent, the interviews will be recorded on the Teams/Zoom recording function (audio only) and stored securely and kept private until they have been transcribed (what you say is written out) and made anonymous. At this point the recordings will be deleted. The interview transcript will be saved in electronic form in encrypted folders on a password protected computer with a secure cloud-based backup. Anonymous excerpts from the interviews will be used to inform the project, and might be presented in the findings of the research.

Students at the University of Exeter process personal data for the purposes of carrying out research in the public interest. We endeavour to be transparent about its processing of your personal data and this information sheet should provide a clear explanation of this. If you do have any queries about the University's processing of your personal data that cannot be resolved by the research team, further information may be obtained from the University's Data Protection Officer by emailing: dataprotection@exeter.ac.uk or at www.exeter.ac.uk/dataprotection.

What are the benefits and costs of taking part?
Taking part represents an investment of time. I hope you will find the research interesting and by taking part you are helping me to learn about this topic, and improve my research skills and experience.

If you change your mind about taking part you can withdraw from the research at any time: please email using the contact details below.

Contacts
For any further queries please contact Emily Willoughby on ew635@exeter.ac.uk.

If you have any concerns about the project please contact Dr James Dyke on j.g.dyke@exeter.ac.uk

Appendix 4 - Consent Form

Participant Identification Number: 00

Climate adaptation in Maputo, Mozambique: Coastal hazards, informal settlements, and communicating risk

1. I confirm that I have read the information sheet dated 27th July 2022 (version no 1) for the above project. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason and without my legal rights being affected.

3. I understand that I can choose to have remote contact with the researchers, using phone calls, video calls, emails etc.

4. I understand that relevant sections of the data collected during the study, may be looked at by members of the research team and module staff. I understand the findings may be looked at by other individuals connected to the University of Exeter.

5. I understand that taking part involves anonymised audio recordings to be used for the purposes of student assessment.

6. I agree to take part in the above project.

Name of Participant	Date	Signature
Name of researcher taking consent	Date	Signature

Appendix 5 - Interview Questions

Se em algum momento da entrevista você desejar dar respostas mais completas em português, fique à vontade para fazê-lo. Estes serão traduzidos com o apoio do meu orientador de dissertação que é falante nativo.

Section 1 - Informal settlements

1. 70% of Maputo's population live in informal settlements. What issues do informal settlement residents experience here?

2. Do informal settlement residents experience barriers to improving their skills, accessing education and social networks?

3. How do you think Maputo Municipality can promote security for informal settlement communities who face a lack of housing/land tenure, informality, and fear eviction?

4. How do you think Maputo Municipality can promote the safety of informal settlement residents in their current housing structures?

Section 2 - Urban Planning

5. What do you think is a priority for urban planners in Maputo?

6. Do you think urban planners in Maputo face many challenges in ensuring safe residential housing?

Section 3 - Climate Change

7. Are Mozambique and Maputo affected by climate change? If yes, how?

8. What impact does climate change have on informal settlement residents?

9. Who is responsible for Maputo's emergency response to natural disasters, such as flooding, storm surges and cyclones?

    9a. Is this organisation(s) prepared to manage impacts of sea level rise as well?

10. Have informal settlement residents been displaced before due to coastal hazards?

11. Have informal settlement residents ever been relocated by the government to protect them from areas prone to flooding, sea level rise, storm surges or cyclones?

12. Have any other interventions been deployed to protect these residents?

13. Are you aware of any organisations trying to increase local knowledge of climate change impacts in Maputo?

13a. If yes, what organisations? What do they do?

13b. Do these organisations include residents of informal settlements in their work?

13c. What can be done to support initiatives that increase local knowledge?

Section 4 - Climate adaptation

14. How important is climate adaptation for Maputo?

15. Are there existing climate adaptation plans and policies?

16. Do you think urban planners have a role in increasing Maputo's adaptive capacity to climate change?

17. What methods of 'upgrading' informal settlements might help residents to increase their resilience to climate change impacts?

18. Is data for Mozambique's weather and climate accessible to policy makers and urban planners?

19. To what extent can this data be refined to help policy makers and urban planners make decisions about adaptation interventions?

20. What might help urban planners be better informed about climate change and coastal hazards?

End

Appendix 6 - Brief outline of national and municipal key plans, strategies, laws and policies included in the content analysis of this project.

National Adaptation Action Plan (NAPA)	The plan includes four initiatives: the prevention of natural disasters; early warning systems; agriculture, environmental, fisheries and water sectors; coastal zones; and erosion control. The plan seeks to contribute also to poverty alleviation and sustainable development.
National Climate Change Mitigation and Adaptation Strategy (ENAMMC)	Objective is to establish action guidelines to create resilience, reduce climate risks to the community and to the economy, while promoting low carbon development .
Law on Disaster Risk Reduction and Management (DRM)	Establishes the legal regime of disaster management and reduction, with a view to making it in line with the challenges posed by the risk of disasters and the need to build resilience to event extremes.
Climate Change and Gender Action Plan (Phase II)	Gender inequality is a significant issue across the country; gender-based discimination has kept women in vulnerable circumstances which will be exacerbated with climate change; seeks to mainstream gender in climate action focussing on water, agriculture, health, mitigation, disaster risk reduction, coasts and fisheries
Action Plan for the Reduction of Absolute Poverty (PARPA II)	The main objective is to reduce poverty by distributing resources to benefit the poorest communities. Priorities include supporting policies that improve national per capita income, closely coordinating projects with the international community to promote flow of aid, and to continue to monitor trends of poverty amongst others.
Master Plan for Disaster Risk Reduction (PDRRD)	Disaster risk reduction is the main way to reduce vulnerability to extreme events across Mozambique; outlines the importance of training and professionalisation of those involved in DRR; main objectives are to improve understanding of disaster risks at all levels, strengthen readiness responses and establish partnerships and international cooperation
Urban Master Plan of Maputo Municipality	Strategic projects include: slum upgrading, land requalification for development of social/public service infrastructure, land provision for urban expansion, the promotion of urban diversification in a bid to prevent peri-urban slums and the spatial segregation of poor communities

Maputo's Resettlement Policy Framework	Resettlement is discussed here purely for urban development, not in regard to reducing climate risk. Involuntary and land acquisition should be minimised or avoided where possible, and displaced people should have the opportunity to participate in planning and implementing resettlement programmes
PROMAPUTO MMDP I and II	MMC partnered with the World Bank to implement this 10 year programme. Phase I addressed legacy issues and financial capacity constraints, while Phase II focussed on management of urban land, ensuring the improvements of neighbourhoods and reduce informal settlements.

Appendix 7 - Coding table from interviews

Themes	**Codes**	**Example quotes from interviews**
Importance of culture	• Don't want to leave their homes • Urban planners should understand the culture of people • Good social network • What makes them return?	Urban planners should understand the culture of local people
		They always come back.
		Business is the chief reason. For some of them that's all they know, so they will come back for access to the city
Role of planning	• Look at other cities • Very important for climate adaptation • Enemies of progress	I'm definitely seeing increasing awareness of climate change in general, which is good... Beyond that, I think it does take a concerted effort. Urban planning course - can we integrate climate change into that - this is what climate risk is going to look like in places where you're gonna be working
		They need to understand risk
Climate data	• Radio bulletin • Planners need to trust the data • Information needs to be credible • How to use climate data	*If you are not a member of this group, you are just going to have the information like other citizens*
		What I believe is you focus on the specific problems that you need to solve. Lets say in Maputo's informal area. You need to go to who is responsible to make changes there, because while urban planners can discuss it, they are not the ones who do decision making for that area
		They have access to that. The climate information is public information that can be provided by the institution. Whenever they want it they can get it. This is available to anyone interested.
Government trust	• Relocation for political gain • [Policy] documents not evidence in real life • Prevention and penalties	Government in Mozambique has a long history of trying to resettle people in order to suit elections
		Under the guises of Disaster Risk Reduction
Informal settlement expansion	• Selling a problem • Giving power to people on precarious land • No planning in advance • Lack of drainage	We lack a coordination between organisations that are the service providers. For example an organisation can provide energy or water [to these areas], so showing that services have operated there.
		They definitely don't have good drainage. I mean, when you drive around Mozambique, you realise that water and sanitation and hygiene is a big issue. Obviously no waste disposal. So I think that's a big risk for kind of disease.
Climate change impacts	• Cyclones • Floods • Doughts • Sea level rise	The coast is experiencing a lot of erosion
		The same places flood again and again
Inequality		These places are not intended for construction

	• Very rich constructing in coastal areas • Informal settlement residents can't cope • Building in coastal areas • Governments don't recognise informal settlements • Suffering	I think it's a Radisson Blu, really fancy kind of five star hotel that's been built within the flood zone
		People are starting to abandon their houses because people cannot cope anymore
Collaboration	• Require an operating and effective master plan • Other institutions need to see urban planning as a key player in climate adaptation • Government commitment is lacking • Build a partnership	So we should warn them and tell them please go to safe place don't build in this place, it's I think it's lack of lack of serious planning from the from the government
		ICLEI's FRACTAL project worked with key decision-maker to integrate climate risk
Capacity building	• Capacity building for individuals • Capacity building for institutions • Radios for communities, powered by solar • What climate change impacts do we want to prevent? • Prevention rather than penalties • Cross-collaboration within government	There must be something between the planning and the execution. I don't know what is failing there.
		Need houses that can withstand environmental pressures
		We should be encouraging prevention, not enforcing penalties
		Cross-collaboration within governments is vital to any climate change adaptation

Appendix 8 - Distribution of Maputo's population (by municipal districts). Source: INE, 2008, in UN-Habitat, 2010).

Municipal District	1997 Population Census	2007 Population Census (Preliminary Data)	Difference 1997-2007
Municipal District Nº 1	154,28	108,353	-45,931
Municipal District Nº 2	162,750	155,264	-7,486
Municipal District Nº 3	210,551	224,181	+13,630
Municipal District Nº 4	228,244	289,864	+61,620
Municipal District Nº 5	211,008	293,716	+82,708
Municipal District Nº 6 (Catembe)	15,853	19,605	+3,752
Municipal District Nº 7 (Inhaca Island)	4,672	3,956	-716
Total	**987,362**	**1,094,939**	**+107,577**

Source: 2007 Census, National Institute for Statistics (Instituto Nacional de Estadísticas - INE, 2008)