RESPONDING TO CLIMATE CHANGE IN MOZAMBIQUE

REPUBLIC OF MOZAMBIQUE
MINISTRY OF STATE ADMINISTRATION
NATIONAL INSTITUTE OF DISASTER MANAGEMENT

Instituto Nacional de
Gestão de Calamidades

National Institute for Disaster Management (INGC)

PHASE II

SYNTHESIS REPORT

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EXECUTIVE SUMMARY

The extent to which Mozambique's vulnerability will increase with increasing exposure to climate change risks will depend on the country's adaptive capacity. Without the implementation of priority adaptation measures, the increasing exposure of people and economic assets will lead to exponential increases in economic loss from climate-related disasters.

The 2012 Intergovernmental Panel on Climate Change SREX report[1] broadened the definition of climate change and placed extreme events right at the forefront of climate change concerns. Over the past few years, particularly in Africa, it has become clear that adaptation to climate change impacts should become central to actions in any climate regime. This was also the message given at the United Nations Framework Convention on Climate Change meeting held in Durban in November 2011, which was taken up by the African countries.

Led by the Mozambican Government's National Institute for Disaster Management (INGC), a scientific study on the potential impacts of climate change in Mozambique was conducted (INGC Phase I, 2008–2009). This research, which was widely quoted and the first to apply downscaled climate change models to Mozambique, provided the country with significant insight into how climate change could impact on national investment and poverty reduction plans over the coming five to 10 years, threatening large portions of the coastline where development is taking place and population settlements are located. It showed that, in Mozambique, climate change and disaster risk go hand in hand, as most of the impacts of climate change would be felt in the form of the worsening risk, spread, intensity and frequency of natural disasters.

A second project focused on the identification of science-based solutions to the potential impacts from climate change. The project, *Responding to climate change in Mozambique* (INGC Phase II, 2009–2012), was organised around three pillars: a *strategy pillar*, a *capacity-building pillar* and an *implementation pillar*.

The *strategy pillar* looked at how Mozambicans need to prepare for climate change impacts by 2030 from a disaster risk perspective and at what actions and funding are needed to achieve this. The *capacity-building pillar* identified the most effective ways to create the necessary in-country skills and information base for essential research and education and to facilitate a good science-policy interface. The *implementation pillar* identified adaptation measures and costs for specific high disaster risk, high-impact areas organised around the themes of coastal protection, early warning, water, agriculture, cities and the private sector.

[1] Intergovernmental Panel on Climate Change. 2012. *Special report on managing the risks of extreme events and disasters to advance climate change adaptation* [Online]. Available: http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-All_FINAL.pdf.
http://www.undp.org.mz/en/What-we-do/Crisis-and-Environment/Ongoing-Projects/Strengthening-Local-Risk-Management-and-Mainstreaming-Disaster-Risk-Reduction-DRR

Box A illustrates the key achievements of the project. This is followed by a summary of key findings and outcomes.

Box A: Key achievements of INGC Phase II

- A detailed vulnerability risk analysis for 11 high-risk coastal cities and towns (based on 14 parameters) was conducted, as was a coarser vulnerability analysis for each kilometre of the entire Mozambican coast (based on seven parameters).
- Priority adaptation measures and costing for the 11 high-risk cities and towns were determined. These range from coastal management options and the definition of safe areas to soft and hard engineering measures.
- An economic rationale of adaptation was calculated for the cities of Maputo, Beira and Quelimane (including net loss averted by 2030 if adaptation measures were implemented, capital expenditure required over the next five years to implement the identified adaptation portfolios and insurance proposals for risk transfer), culminating in a city adaptation strategy for 2010 to 2015.
- A complete business plan, with costing and legal structures, was compiled for the Centre of Knowledge on Climate Change, including four core goals (research, advisory services, awareness/dissemination and training), which were established in consultation with key stakeholders.
- An early-warning water decision support system was developed for the entire Zambezi basin, covering 1.4 million km^2 (almost double the size of Mozambique), to simulate the impacts of climate-induced changes and new water resource developments (such as irrigation projects and dams) on downstream infrastructure and water availability. This system is expandable to other river basins.
- Early-warning mapping of changes in inundation and risk areas resulting from climate change was done for the Zambezi, Limpopo and Pungwe rivers. Measures were recommended and costing was also done.
- An urban flooding analysis was conducted and detailed solutions, with costing, were proposed for a high-risk location in Maputo. This is expandable to other high-risk locations.
- The first-ever O_3 meters in Mozambique were installed in Caia (Sofala) and Mabote (Inhambane), along with light and CO_2 meters, to demonstrate the impact of (increasing) ground level O_3 on crop yield.
- Four commercially viable adaptation programmes were developed in partnership with the private sector, each worth US$50 million to US$100 million of private-sector investment over a five-year time-span.
- Following consultations throughout Mozambique, a national strategy was drafted outlining what Mozambique should achieve by 2030 if it is to mitigate the increasing disaster risks of climate change.
- A GeoNode website (moz-adapt.org) and an information portal (ingc.dirisa.org) were established where the above-mentioned results and related databases are made accessible at varying levels to professionals and the general public.

Key findings and outcomes

Strategy pillar

- A national strategy on climate change should aim to protect the environment for future generations and, at the same time, provide present generations with security and protection, which translates into the prevention or reduction of vulnerability. This last-mentioned dimension is urgent in Mozambique and making it subordinate to the longer-term environmental protection dimension will have implications for the Government's responsibilities.

- In designing the national strategy, the reality of the country, its culture and governance practices, existing capacities and, above all, its most pressing problems must be borne in mind. In Mozambique, the greatest impact of climate change in the coming years will be in the form of increasing exposure to natural disasters. Disaster risk management should therefore be the central pillar of the national strategy on climate change for the next 20 to 25 years, followed by sectoral adaptation priorities, mitigation and transversal issues, such as capacity building and information management.

- The very actionable national strategy on disaster risk reduction, developed by the INGC as part of this study and approved by the Coordinating Council for Disaster Management (June, 2012) can be incorporated into the overall national strategy on climate change. This will be successful only, however, if crucial aspects, such as financial and coordination mechanisms, are defined in a flexible manner and do not depend on a single ministry or sector.

- The strategy will be successful if Mozambique allocates adequate and timely priority to the funding and execution of the outlined adaptation. Through the implementation of the strategy, the participating parties bear the responsibility of providing the people of Mozambique with the protection and sustainable development that they need in this era of climate change.

Capacity-building pillar

- The demands of addressing climate change are such that officials and policy makers must constantly learn and retain information about an enormous range of topics and issues, which themselves undergo rapid change. The only way in which they can do this is to rely on concise, clear, reliable information from various sources. To help Mozambique proactively build its knowledge base and the required information management capacity, the Centre of Knowledge on Climate Change was designed.

- Through awareness creation, research, education and advisory services, the Centre of Knowledge on Climate Change aims to enable all Mozambicans to respond to the risks and opportunities associated with climate change in a sustainable manner. A budget of US$350 000 in the first year and between US$1.2 million and US$1.5 million in subsequent years would allow approximately 1 000 Mozambicans to attend professional programmes in an optimal ratio of technology-to-science development as well as six to 10 research programmes and four advisory projects or targeted information campaigns to be implemented annually. After an initial set-up phase funded by generic sources, the Centre should become financially sustainable within the space of three years using project funding and direct revenues from services. The independence of the Centre envisioned by the stakeholders would be safeguarded with the enrolment of independent heads of science and services and with the setting up of the proposed governance team. The Centre would have a lean, central office in Maputo and three additional teams in different provinces.

- Underlying all the activities of the Centre of Knowledge on Climate Change is a web-based content management portal (ingc.dirisa.org[2]) for secure information storage, dissemination, retrieval and discovery (links, maps, videos, reports etc.) linked to a GeoNode site (moz-adapt.org[3]) for the management and publication of geospatial and meta-data, interactive map building etc. These sites aim to promote broad collaboration among institutions and will be accessible to different target groups. The Centre itself will act as a one-stop shop or platform for citizens, authorities, business people and specialists to ask questions and find updated knowledge.

Implementation pillar

- Based on an assessment of the most important drivers of risk to coastal erosion, of hazards and of impacts, an increase in disaster risk along the coastline is expected to occur progressively. The consequences of the impacts, however, are expected to increase exponentially.

- The levels of coastal vulnerability for 11 coastal cities and towns were determined and coastal adaptation plans were mapped. The most vulnerable city is Beira, followed by Tofu, Pemba, Xai-Xai beach, Maputo, Ilha de Mozambique, Ponta d'Ouro and Vilanculos. The least vulnerable towns are Maxixe, Quelimane and Nacala. *Virtually all the areas (from sheltered to exposed locations) below the +5 m contour line relative to mean sea level (MSL) in these cities and towns are already highly vulnerable to extreme events during mean high-water spring with the low scenario* of 1 m sea-level rise (SLR) by 2100 or approximately 0.3 m to 0.5 m SLR by 2050. Some of the cities and towns will, *on average*, be highly vulnerable to the impact of climate change, while every city and town will have at least several locations that are highly vulnerable to the impacts of climate change by 2050, based on the most likely future case scenario.

- Without intervention, most of Beira is already at extreme risk of flooding and only the high area a few kilometres inland to the north is at low risk. A coastal adaptation plan for Beira summarises the preferred adaptation options along each 0.5 km section of the western, southern and south-eastern Beira coast. Existing infrastructure is already too low (in other words, it excludes SLR) and therefore needs to be upgraded and maintained as a matter of urgency. Where possible, new developments should be located above the +8 m MSL to offer protection against a combination of a cyclone at spring tide (with a +4.9 m MSL reach) with wave run-up of +1.5 m at a +1 m SLR. In the absence of appropriate adaptation measures, critical infrastructure should be built above the +10 m MSL. C*oastal development set-back lines* must be (re)defined, seaward of which fixed structures, such as houses and roads, should not be built so that they are protected from the physical impacts of sea storms, wave erosion and wave run-up.

- The city of Maputo, like Beira, contains extensive infrastructure and development within the coastal zone that is potentially subject to climate change impact. The most vulnerable area in Maputo in the short term is the approximately 6 km stretch of coastal road along the beachfront up to Costa Do Sol, followed by the eastern part of the port area where existing infrastructure is already too low in places for current conditions and therefore needs to be upgraded and maintained as a matter of urgency. Planned coastal infrastructure, including sea-wall or revetment protection and coastal road reconstruction, must be reviewed to take the effects of climate change into account.

- The minimum investment needed for priority coastal adaptation measures for Beira is in the order of US$27 million and, for Maputo, in the order of US$50 million. This includes the costs of soft and hard engineering measures but not the management options (A1 to A4, such as accept and retreat, and zoning), which require in-depth socio-economic studies.

[2] The name will change once the Centre has been launched.

[3] Designed and set up by the World Bank Open Data for Resilience Initiative.

The maximum costs could be tenfold these values, depending on site-specific engineering designs, the chosen technology and environmental investigation results.

- The mayors of impacted municipalities must engage to facilitate the successful incorporation of the no-regret priority measures and other recommendations in the current and in future structure plans as well as private-sector investments. Critical shortages of skills and management capacity within municipalities must also be addressed. Ongoing climate change initiatives must furthermore be well coordinated to avoid confusion and conflicting recommendations at municipal level.

- Mozambican cities are already losing GDP through climate change impacts[4] – and these impacts are set to become more severe. An economic analysis on the impact of climate change on the entire cities of Maputo, Beira and Quelimane (in other words, not only the coastal areas of these cities) reveals that the current expected loss for Beira of approximately US$20 million could increase fivefold by 2030 to between 5% and 9% of GDP[5]. For Maputo, the current expected loss of approximately US$50 million could increase three to fivefold by 2030 to between 4% and 5% of GDP. Quelimane's current expected climate-related loss of about US$8 million could increase to between US$40 million and US$45 million by 2030 or to between 4% and 5% of GDP. This expected loss is an average that can mask the potentially devastating impact of lower-frequency events, resulting in years with more significant losses.

- Part of the expected loss for each city could be averted through the implementation of adaptation measures. If recommended measures with a cost-benefit ratio of less than 1.5 were implemented, the expected loss averted by 2030 for Beira would be in the order of between US$60 million and US$70 million, approximately US$80 million for Maputo and approximately US$15 million for Quelimane. Beira could reduce the economic impact of disasters by approximately 43% under the moderate climate change scenario and Maputo and Quelimane by approximately 37%.

- Despite a strong economic rationale to start adaptation sooner rather than later, the recommended measures represent very significant investment. Capital expenditure investment for cost-effective measures for the city of Maputo as a whole would amount to approximately US$400 million[6] over the next five years. Beira would require approximately US$270 million over five years, mostly for coastal interventions, and Quelimane would require approximately US$40 million, mainly for inland flooding measures. These costs surpass municipality and central-government budgets, and external and private-sector investment would therefore be necessary in the coming years.

- Insurable losses are significant in all three cities of Maputo, Beira and Quelimane, which would greatly benefit from risk transfer mechanisms. These concern low-probability, high-impact events, as losses from events occurring with relatively high frequency could be avoided cost effectively through adaptation measures. For the type of hazards faced by the three cities,

[4] Benson, C. & Clay, E. 2001. *The impact of drought on sub-Saharan African economies.* Technical paper 401. World Bank; World Bank. 2005. *Memorandum – The role of water in the Mozambique economy identifying vulnerability and constraints to growth.*

[5] Corresponding to the moderate and high climate change scenario, respectively.

[6] This figure (as for Beira and Quelimane) is restricted to measures with a cost-benefit ratio of less than 1.5. A comprehensive coastal-only cost-benefit analysis is contained in the INGC Phase II report on coastal protection.

parametric insurance or a combination of parametric insurance and contingent financing is recommended. Insurance cost curves were calculated for different types of hazards for Maputo, Beira and Quelimane. Municipalities can use these curves to determine their preferred range of coverage and deductible, and calculate the total annual cost of insurance for the cities.

- Economic analysis suggests that Mozambique, even with the losses from climate change becoming more severe, should set its ambition level to curb losses from climate change to 50% of the current level. To meet this ambition level, Mozambican cities should begin a five-year investment plan in adaptation measures, with specific investments tied to avoided losses from projected adaptation benefits. Five-year plans are proposed for Maputo, Beira and Quelimane, mapping out the major priorities for each year to set the municipalities on the path to halving the current per cent of GDP impacts of climate change by 2030.

- The agricultural sector is crucial to the development of Mozambique. Analysis shows that climate change poses a threat to the Government's current strategic plan to double yields by 2020, as the impacts of climate change will demand significantly more[7] effort to attain the targeted levels of yield. As a consequence of these impacts, climate change is likely to aggravate food insecurity in Mozambique, putting the country's efforts to reduce poverty at risk.

- This study shows that, on average, annual crops lose approximately 5.4% in yield with each degree Celsius increase in average temperature. The overall projected reduction for maize by 2040 to 2065 is approximately 11% of present yield, although this figure masks higher reductions in specific areas, such as in the area around Tete, where up to between 30% and 45% decreases could be expected. The strongest decreases would spread from the Tete area towards the Sofala coast and on towards the south. Yields could further decrease due to the projected increase in the frequency and intensity of disasters.

- Studies for Mozambique to date have assumed crop transpiration (water) and temperature to be the main restricting factors of yield. While these are indeed important factors, there is another factor that, in many cases, has a higher impact on yield levels than water and temperature: ground-level O_3. It is, in fact, ground level O_3 increase that has the most negative impact on yield, followed by temperature increase. O_3 is released during land burning practices at the start of the planting season and adaptation measures should therefore include the adjustment of plantation dates to avoid a high O_3 concentration, the development of crop varieties that are tolerant to high O_3 levels, the avoidance of wild fires and a switch to cold fires to avoid high NO_2 emissions and the consequent production of O_3.

- Water management remains key, as climate change combined with development and population growth will increase the demand for water, which is already becoming less available. There is a large potential for poverty reduction through small interventions in rain-water harvesting and storage in smallholder settings in semi-arid and sub-humid areas. The provision of 1 000 m^3 of extra water per hectare per season, in combination with improved crop management (dealing with the O_3 factor) and soil nutrient management, could substantially increase the productivity of small-scale rain-fed agriculture and farmers' resilience to dry spells.

- The question of how to safeguard water supply on the one hand and improve early warning against floods and droughts on the other hand could be addressed largely by

[7] The Strategic Plan for the Rural Sector Development (PEDSA 2011–2020) demands a doubling of yield by 2020, in other words, an increase of 100%. Our findings demonstrate that, with climate change, an increase in yield of 150% by 2020 must be targeted.

improving information systems. A decision support system was developed for the entire Zambezi basin, covering 1.4 million km² (almost double the size of Mozambique). This tool can spatially assess the impacts from climate-induced changes on water supply downstream and by sub-basin (and in catchment areas outside Mozambique), new water resource developments (such as dams and reservoir construction or upstream irrigation projects) and changes in land use. What-if questions, such as "What if the temperature increases by 3° C and precipitation decreases by 10%?", can be easily simulated for any time slice between 1950 and 2100.

- The decision support system (using three general circulation models) projects an increase in temperature of between 1° C and 2° C for the period up to 2050 and between 4° C and 5° C for the period 2070 to 2100 across the entire Zambezi basin. In addition, a warming by 1° C will result in an increase in potential evapo-transpiration by 2.5%[8] across the basin. Precipitation in the upper regions of the basin, in other words, upstream of Victoria Falls, is projected to decrease significantly (by up to 30%). Downstream of Victoria Falls, an increase in precipitation is projected, which will lead to high increases in river discharge, notably in the Shire River, which is already prone to flooding.

- The decision support system can simulate the implications of development on water availability for hydropower under climate change conditions. This was done for two projects with a particularly high impact on the hydrology of the river: the Batoka Gorge dam upstream of Kariba and the Mphanda Nkuwa downstream of Cahora Bassa, both expected to be completed by 2024. The impact of the development on river discharge is clearly visible for both periods 2021 to 2050 and 2071 to 2100, with the highest impact in the high-development scenario during low-flow months, showing almost no river flow at Tete during a considerable part of the period 2071 to 2100. Under this scenario of climate change and high development, the planned operational rules (included in the decision support system) would clearly need to be adjusted.

- Improvements in hydro-meteorological monitoring and in the observation network, including data processing and storage, are essential for future endeavours by Mozambique to carry out detailed flood risk assessments and to plan river-related developments. For example, while the decision support system, combined with flood modelling, can identify changes in flood risk resulting from climate change and/or development, current data availability does not allow for the accurate identification of safe areas (which requires predictions on the depth of flooding).

- A separate study on the Limpopo basin helps decision-makers to target priority districts with appropriate preventative interventions. The study mapped the districts where the combination of social vulnerability and increased risk in magnitude and frequency of flooding is highest. These sub-basins are scattered around the perimeter of the Limpopo basin in the west and south-west and in the north-east. Sub-basins at risk from the greatest decreases in flow are located predominantly in the south-west of the basin; this is also where the districts with the highest vulnerability index are located (Massingir and Chicualacuala). Adaptation interventions here should focus on countering the impacts of the projected decreases in flow. Sub-basins with the highest increase in probability of crop failure during the October-November-December planting season are located in the south-east of the basin.

- The private sector investing in Mozambique has both an opportunity and a responsibility to contribute to the building of resilience to

[8] This relationship was obtained at all the stations in the Zambezi basin; this rate in increase in potential evapo-transpiration is also scalable for higher degrees of warming.

climate change. A blueprint process for the climate proofing of investment opportunities was developed and successfully tested in a pilot public-private adaptation project in Cabo Delgado (a bio-ethanol, bio-electricity and food production project). Sustainable investment-opportunity maps were generated to identify areas that are most suitable for particular types of land use and investment (given climate change) and that need to be conserved to satisfy ecosystem service supply and demand. Adaptation opportunities were then identified at three levels, namely within company operations and supply chains, in partnership with surrounding communities, and in collaboration with the wider community.

- A second private-sector study put forward four commercially viable adaptation programmes (nationwide) that would have both a high impact on climate resilience and high relevance for the private sector, thus providing a meaningful and realistic opportunity for third-party private-sector investment. The selection process started with a strategic analysis of the Mozambican business context to identify and map high-risk, high-(investment)impact areas and then went onto cost-benefit analyses, barriers to investment analysis and recommendations on the facilitation of implementation. Private-sector partners were identified for the four programmes (in the areas of community energy, composting, micro-finance and insurance), each with a five-year private-sector investment value in the order of US$25 million to US$50 million). Without a portion of public funding to undertake the pilot projects of these first programmes and without proactive government support, however, the private sector would not be interested in making the required investments from its side, as the costs and barriers would be too great.

- Risk-sharing and transfer mechanisms on a local and national scale, such as micro-insurance, insurance and reinsurance, would provide the means for finance relief, the recovery of livelihoods, reconstruction, and knowledge of and incentives for reducing risk. No major insurance player currently has a real presence in Mozambique. The opportunity in Mozambique for insurance companies compared to the lack of understanding and uncertainty makes working in the country a difficult proposition. A stable regulatory framework and strong governance are needed if a higher penetration of products is to develop. Insurers are interested in participating in a pilot project with a balanced portfolio of prevention, intervention and insurance measures, which could be used to increase awareness of appropriate climate risk management.

- The costs of using the environment and natural resources are higher for those who decide to take on adaptation and the responsibility for costs, which have often, to date, been considered to be externalities. Private-sector investment in adaptation measures beyond corporate social responsibility involves long-term, proactive engagement and will take place only if the overall economic environment is attractive.

- Commitment and political leadership at the highest levels are necessary if Mozambique is to be positioned as an obvious target for foreign investment to reduce vulnerability to climate change. This would require the setting of ambitious goals and the creation of the necessary competencies and of a management model involving a unique point of contact for private-sector investors.

- To facilitate shifting the investor paradigm of “business as usual” to that of “sustainable in the long term,” the Government should encourage the implementation of adaptation on land identified as suitable and available for investment (after considering climate change impacts) and proactively invite a selection of corporate-responsible investors to act as role-models to others in the sector. To support the introduction of green technology, the Government should ensure covering the difference in cost between the installation of standard technology and that of improved, energy-efficient technology. The legal framework of the country will need to be adjusted to align it with the new concepts, objectives and political measures imposed by climate change, thus offering a harmonious framework for the implementation of the proposed measures and programmes.

- Climate change is not about what might happen at the turn of the century – it is urgent now, as climate-related issues and impacts are already apparent in Mozambique. *No-regret* measures have been identified for 11 coastal cities and towns in the agriculture and water sectors for immediate implementation. The most effective risk management, however, will involve the implementation of a portfolio of actions in determined areas, as opposed to a singular focus on any one type of action. The science-based coastal protection plans, city strategies, agriculture and water plans, capacity-building plans and performance and impact monitoring plans offered by this project provide an opportunity for Mozambique proactively to reduce the vulnerability and exposure of its people to climate change impacts.

CONTENTS

figures, tables & boxes

abbreviations and acronyms

CCGC	Coordinating Council for Disaster Management
CONDES	Sustainable Development Council
CRU	Climatic Research Unit
CUE	carbon-use efficiency
DNA	National Directorate of Water
INAM	Institute of Meteorology
INGC	National Institute for Disaster Management
IPCC	Intergovernmental Panel on Climate Change
MHWS	mean high-water spring
MICOA	Ministry of Coordination of Environmental Affairs
MINAG	Ministry of Agriculture
MSL	mean sea level
OECD	Organisation for Economic Co-operation and Development
P&L	profit-and-loss statement
SETSAN	Technical Secretariat for Food Security and Nutrition
SLR	sea-level rise
STIIMC	Inter-Institutional Technical Secretariat for Climate Change
SuDS	sustainable drainage systems
WBCSD	World Business Council for Sustainable Development

1: INTRODUCTION

This report aims to inform the Government of Mozambique, the people of Mozambique, donors, academics, the business community and civil society about the achievements of the project "Responding to Climate Change in Mozambique", also called "INGC Phase II", led by the National Institute for Disaster Management (INGC) in Mozambique.

The predecessor to this project, INGC Phase I, determined the impact of climate change in Mozambique (INGC, 2009). The report was widely quoted worldwide, including by international donors, universities and national institutions, helping to create awareness about the potential dramatic consequences for Mozambique and the need for immediate action and planning. The main Phase I report concluded the following:

As a result of climate change, the exposure to natural disaster risk in Mozambique will increase significantly over the coming 20 years and beyond. Temperatures in Mozambique may rise by as much as 2 to 2.5˚C by 2050 and 5 to 6˚C by 2090 (depending on the region); Rainfall variability will increase; there will be likely shifts in the start of rainy seasons with wetter rainy seasons and drier dry seasons. Flood risk will increase notably in the South. The central regions will be most heavily impacted by more intense cyclones and sea level rise, as well as drought risk around the Cahora Bassa area.

Up to approximately 2030, more severe cyclones will pose the biggest threat to the coast; beyond 2030, the accelerating sea level rise will present the greatest danger, especially when combined with high tides and storm surges. The city of Beira is already in a very vulnerable situation, with inadequate coastal protection for annual return events. Parts of Maputo, as well as other coastal areas such as Pemba, Vilankulos and nearby islands, are also already at risk.

INGC Phase II, which ran from September 2009 to April 2012, concentrated on identifying and designing adaptation solutions to the climate change impacts found during INGC Phase I. A total of 20 disciplines, 16 institutions and 44 experts (50% of whom were national) were involved. The project consisted of the following three pillars: a *strategy pillar*; a *capacity-building pillar*; and an *implementation pillar*. All three pillars emphasised the combination of disaster risk reduction and climate change adaptation.

The *strategy pillar* looked at how Mozambicans need to prepare for climate change impacts by 2030 from a disaster risk perspective and what action and funding are needed to achieve this.

The *capacity-building pillar* delivered the following through wide stakeholder consultation: a complete business plan for a centre of knowledge on climate change; early-warning decision support systems and training; a user-friendly information portal containing all databases and findings of INGC Phase I and II; and a dissemination strategy to help create awareness on climate change risks for the Government of Mozambique at all levels and with the Mozambican urban and rural population.

The *implementation pillar* identified adaptation measures for specific high disaster risk and high impact areas and started the implementation of some of these measures. The adaptation measures are organised around the themes of coastal protection, water, preparing cities, building resilience in partnership with the private sector and food security. Cost estimates for all adaptation options were provided.

Preliminary key findings of INGC Phase II were presented to the Coordinating Council for Disaster Management (CCGC) on 19 September 2011. The CCGC was attended by ministers and chaired by the Prime Minister. The CCGC recommended that the INGC should

- elaborate, as a matter of urgency, the national strategy on disaster risk reduction and climate change adaptation,
- disseminate the results to different levels (local, provincial and national) and transfer the acquired knowledge to academic institutes at all levels,
- incorporate the findings of the study into existing and ongoing intervention plans at municipal level,
- establish a centre of knowledge on climate change and
- establish a unique point of contact for investors, for the provision of information on adaptation programmes and for the promotion of partnerships for co-financing adaptation measures.

These action points are ongoing and will be continued during the next project, INGC Phase III, as full implementation will require additional funding. INGC Phase III will concentrate on ownership and implementation. Many potential solutions and opportunities were designed during INGC Phase II; the next step is actual implementation, for which understanding and ownership of the problems and solutions by municipalities, farmers, communities, the private sector and other groups are a prerequisite.

This report highlights only a selection of the most important findings of INGC Phase II. The full report will be presented during the end seminar of INGC Phase II and the launch of Phase III, planned for the third quarter of 2012. All reports will be accessible through the new information portal on climate change to be hosted by the proposed centre of knowledge on climate change.

2: PILLAR I: NATIONAL STRATEGY ON DISASTER RISK REDUCTION AND CLIMATE CHANGE ADAPTATION

"It is better to prevent than to cure." – INGC, Mozambique

Mozambique has a well-functioning disaster risk management system at various levels, which will serve as the basis for the national strategy on disaster risk reduction and climate change adaptation.

The global and national reality, however, shows that the framework for natural disasters and their impacts on the lives and welfare of communities is changing and making way for the emergence of a framework on a larger scale, thus demanding a response on a larger scale.

The national strategy on disaster risk reduction and climate change adaptation outlines the *vision* and *mission*, *guiding principle*, objectives, actions and resources necessary to increase the resilience of citizens and communities to deal with the impacts resulting from climate change.

The *vision*, as presented by the strategy, is for Mozambique to become "a country with elevated alert levels and awareness of climate change by citizens and communities, whereby, as a result, the risk of exposure to vulnerability is minimized while the country as a whole benefits from the development opportunities offered by international solidarity around climate change".

The *mission* of the strategy is "to prepare and capacitate people for action at a larger scale".

The *guiding principle* behind the strategy is "Prevention Is Better Than Cure", which is also the motto of the INGC.

The five pillars of the strategy are:

(i) preparing and enabling people,
(ii) capacity-building and institutional coordination,
(iii) planning, budgeting and financing,
(iv) communication and information and
(v) building resilience in partnership with the private sector.

Six of the key objectives of the strategy are

(i) within 20 years, to reduce (by 15% to 20% of the 2012 baseline) the levels of vulnerability of those urban and rural communities most exposed to the risks and impacts of climate change,
(ii) within 10 years, to produce and disseminate quality knowledge of international standard on climate change and adaptation strategies for disaster risk reduction,
(iii) within five years, to enable all communities in high disaster risk areas to respond with local means and resources to the challenges posed by climate change, in particular with actions of prevention, risk reduction and emergency response,
(iv) within five years, to prepare the country to function in a coordinated and articulated manner at sectorial and territorial level on the transversal subject of climate change and disaster risk management,
(v) within five years, to prepare cities in the most at-risk areas for a new era dominated by adaptation to climate change and

(vi) within five years, to bring the private sector to contribute meaningfully to all national efforts of adaptation, including to the planning and implementation of investments and to the financing of adaptation and disaster risk-reduction activities, where the aim is to ensure that all newly approved developments explicitly include (100%) climate change response measures.

Seven of the key activities of the strategy are

(i) promoting and increasing concrete projects for disaster risk reduction through climate change adaptation in various provinces as the country gains the capacity to conceptualise and implement the required type of actions,
(ii) establishing a centre of knowledge on disaster risk reduction through climate change adaptation and providing the country with the skills and evidence for decision-making on effective adaptation actions by 2015,
(iii) within five years, providing local committees for natural disaster management in high-risk, high-impact areas with the capacity and equipment to respond to natural disasters aggravated by climate change, including adherence to regulations,
(iv) within 10 years, ensuring coordinated action by the different community committees established under various legislations on land and other natural resources, jointly with the sector responsible for rural development, through the promotion of consultation forums, including adherence to regulations,
(v) by 2015, operating, quality controlling and maintaining an interactive early-warning decision support system and information portal for all metadata, research and reports related to climate change and disaster risk reduction,
(vi) by 2015, implementing insurance programmes for the risk transfer of certain categories of disasters and
(vii) by 2020, implementing city strategies on climate change adaptation for disaster risk reduction in at least three coastal cities.

The budget required to implement the national strategy on disaster risk reduction and climate change adaptation over the first five years (from 2012 to 2016) of its 25-year lifespan is in the order of US$324 million, broken down in Table 1 below and further detailed in the strategy document annex. An operational plan has been drafted to start the implementation of the strategy, called the "INGC Phase III: Ownership and Implementation".

Table 1: Strategy on disaster risk reduction and climate change adaptation: First five-year budget

PILLARS	BUDGET (THOUSAND US$)					
	2012	**2013**	**2014**	**2015**	**2016**	**Total**
I: Preparing and enabling people	37 140	52 750	53 450	63 300	73 300	279 940
II: Capacity-building and institutional coordination	2 310	3 035	3 005	4 725	4 450	17 525
III: Planning, budgeting and financing	425	950	930	930	930	4 165
IV: Communication and information	420	850	1 145	1 740	985	5 140
V: Building resilience in partnership with the private sector	850	1 960	2 530	5 530	5 330	16 200
Monitoring and evaluation	200	300	300	375	520	1 695
TOTAL	**41 345**	**59 845**	**61 360**	**76 600**	**85 515**	**324 665**

Institutional arrangements

The current institutional arrangements for dealing with the impacts of climate change lead to parallel decision-making through two councils, namely the Sustainable Development Council (CONDES), on the one hand (for climate change and the environment), and the CCGC, on the other hand (for climate change and disaster risk). This can result in contradictory decisions being presented to the Council of Ministers and the President of the Republic, and there is no formal system in place to prevent this.

Worldwide experience and dominant literature hold that climate change entails the following four categories of challenges and actions:

- Environmental protection, which emphasises low carbon development through mitigation.
- Scientific research and the forecasting of events and impacts arising from climate change.
- Disaster risk management.
- Adaptation (how economic and social activities can be realised under conditions caused by climate change, in other words, the prevention of negative impacts caused by extreme natural phenomena on economic and social activities).

While there is interconnectivity among the four dimensions, the three last-mentioned dimensions (the forecasting of events and impacts, disaster risk management, and adaptation) are regarded as being more linked with the issue of vulnerability reduction. The first dimension (low carbon development and mitigation) deals with the avoidance of stagnation or regression in the economic growth of a country (employment generation, consumption levels, quality of life, clean energy and environmental balance).

Depending on the context of the country, one dimension may be revealed or associated with two or more of these dimensions. What is essential is the reality of the country, its culture and governance practice, its existing capacities and, most of all, its most pressing problems.

In Mozambique, where it is known that climate change impact will expose the country more to natural disaster risk in the coming years, disaster risk management should be the central pillar of the national strategy on climate change, at least in the coming 20 to 25 years. The strategy could contain four pillars: disaster risk management, adaptation, mitigation and cross-cutting issues.

The proposal of any institutional arrangement should take the following into consideration:

- Both disaster risk management and environmental management as well as adaptation and mitigation are already being implemented in Mozambique. In some of these spheres, the country serves as an example for many other countries (particularly in adaptation and disaster risk management).
- The above therefore implies that practices, institutions and structures are already in place and functioning and are dealing with these issues, albeit with deficits in terms of capacity and coordination.
- The issue of climate change is not limited to environmental management or to disaster risk management.
- In the Mozambican legal and institutional framework (CONDES, CCGC, CES, the Technical Secretariat for Food Security and Nutrition [SETSAN], CCSSSB etc.), by law and in practice, a coordinating role in respect of the actions demanded by the national strategy on climate change does not exist.

A look at the organisation and functioning of the Government in respect of the above-mentioned four pillars suggests the following distribution of responsibilities and mandates for the coordinating entities (inter-ministerial councils and commissions) and sectoral ministries for the objectives envisaged in each pillar to be attained:

Table 2: Distribution of responsibilities and mandates

Pillar	Objective	Components	Government coordinating level	Institu-tional leader-ship	Key actors
Disaster risk management	Decrease loss in human lives, goods and infrastructure through disaster risk and vulnerability reduction.	- Prevention - Evaluation of damage and loss - Evaluation of risk - Protection of infrastructure - Protection of people and goods - Social action - Municipal management - Organisation and enabling of communities - Education and preparation of new generations - Public health - Food and nutritional security - Commercial activity	CCGC	INGC	- INGC - Citizens and communities, including community leaders - Local governments - Municipalities - MMAS/INAS - MINED - MISAU - Academics - SETSAN - MIC - Private sector - NGOs
Adaptation	Optimise the production and management of natural resources and the building of new infrastructure facing the impacts of extreme natural phenomena.	- Agriculture - Fisheries - Water - Public Works - Transport and Communication - Tourism - Energy - Mining - Forestry and Fauna	CES	MPD	- MINAG - MOPH - MTC - MITUR - ME - MINAG/DNTF - MITUR/DNAC - MICOA - Agents of productive sector and infrastructure (public and private)

Pillar	Objective	Components	Government coordinating level	Institu-tional leader-ship	Key actors
Mitigation and low carbon develop-ment	Reduce and avoid damage to the environment due to human activity.	Environmental Management Land Administration Land Ordening Productive sectors (public and private): agriculture, fisheries, water, public works, transport, tourism, energy, mining, forestry	CONDES	MICOA	- MICOA - MINAG/DNTF - MICOA/DNAPOT - Agents of productive sector and infrastructure (public and private)
Cross-cutting issues	Increase the capacity of the country to forecast phenomena and impacts resulting from climate change, adequate technological means and resources, and information and knowledge.	Scientific research Information management and dissemination Transfer of technology Planning and budgeting for climate change Policies and legal frameworks Financing and negotiation	CNCT CNCT CNES	MCT MINED	- INAM - Centre of Knowledge on Climate Change) - Universities - ACM - INIA - MPD - Min. of Justice - Min. of Finance

A practicable and implementable mechanism starting from what already exists and accepted by all parties is needed. The current lack of a body or mechanism for operational and financial coordination should be addressed through the adoption of a mechanism that goes beyond a ministerial level or sector and that represents high political commitment, flexibility, completeness of scope and acceptability (consensus), technical ability and impartiality towards directly benefiting sectors.

Such a mechanism could be the existing Inter-Institutional Group for Climate Change, which could be institutionalised by law passed by the Council of Ministers and eventually renamed as the Inter-Institutional Technical Secretariat for Climate Change (STIIMC). It could consist of national directors and other senior officials of the ministries and key institutions, such as the INGC, INIA and the Institute of Meteorology (INAM).

To give it high political significance and, at the same time, emphasise the centrality of the dimensions of environmental management, risk management, and development planning and budgeting for climate change, the STIIMC could be chaired by the minister responsible for the sector of environment, assisted by two vice-presidents, the director-general of the INGC and a national director from the MPD.

Each of the four pillars could represent a working group within the STIIMC, coordinated by a national director from the ministry with a leadership role in the pillar, whereby cross-cutting issues could consist of various groups, including research and technology transfer, policies and legal reform, and funding and negotiation, which could be coordinated by a national director from the ministry with a leadership role in the pillar.

The STIIMC could have a general technical board with the following functions: the coordination and technical guidance of the implementation process; the development of proposals and implementation plans, the assessment and approval of projects to be implemented and funded under the ENMC, and the monitoring of projects implemented within the ENMC. The STIIMC could therefore be responsible for ensuring the receipt and use of funds derived from multilateral mechanisms and agreements and earmarked for the national strategy. For this purpose, a dedicated account could be opened and institutionally based in MPD or MF (as decided by the Government), through which the STIIMC could manage project funding. In this way, the STIIMC and the climate change account could work together as the implementing entity of climate change projects in the light of international multilateral conventions and agreements. This financial arrangement would apply mainly to the multilateral funds and would not exclude the existence of other accounts or channels.

The financial mechanism proposed here is an alternative to the mechanism proposed by MICOA in the context of the ENMC. It has the following advantages:

- It is not an institutionalised or customised fund, as is the case in respect of FUNAB, the financial sustainability of which is questionable.
- It capitalises on the momentum generated at GIIMC level, including the work relationship created, and it consolidates the spirit of the institutional coordination that is needed for a successful strategy.
- It is staff-ready for operation and does not need strengthening in capacity or reform.
- It entails less management and fewer administration costs.
- It is a more attended, participatory, transparent, flexible process without red tape (it does not need any order to deliberate or analyse any proposal for funding).
- Both the technical coordination mechanism (STIIMC) and the fund (single account) comply with the impartiality required for the sectors implementing ENMC proposed actions.

- It facilitates information and data systematisation, including on projects and funding.
- Neither the fund nor the strategy itself has an owner, since they both belong to the country.

Figure 1 illustrates the lines of supervision and communication in the context of the proposed institutional and financial arrangement.

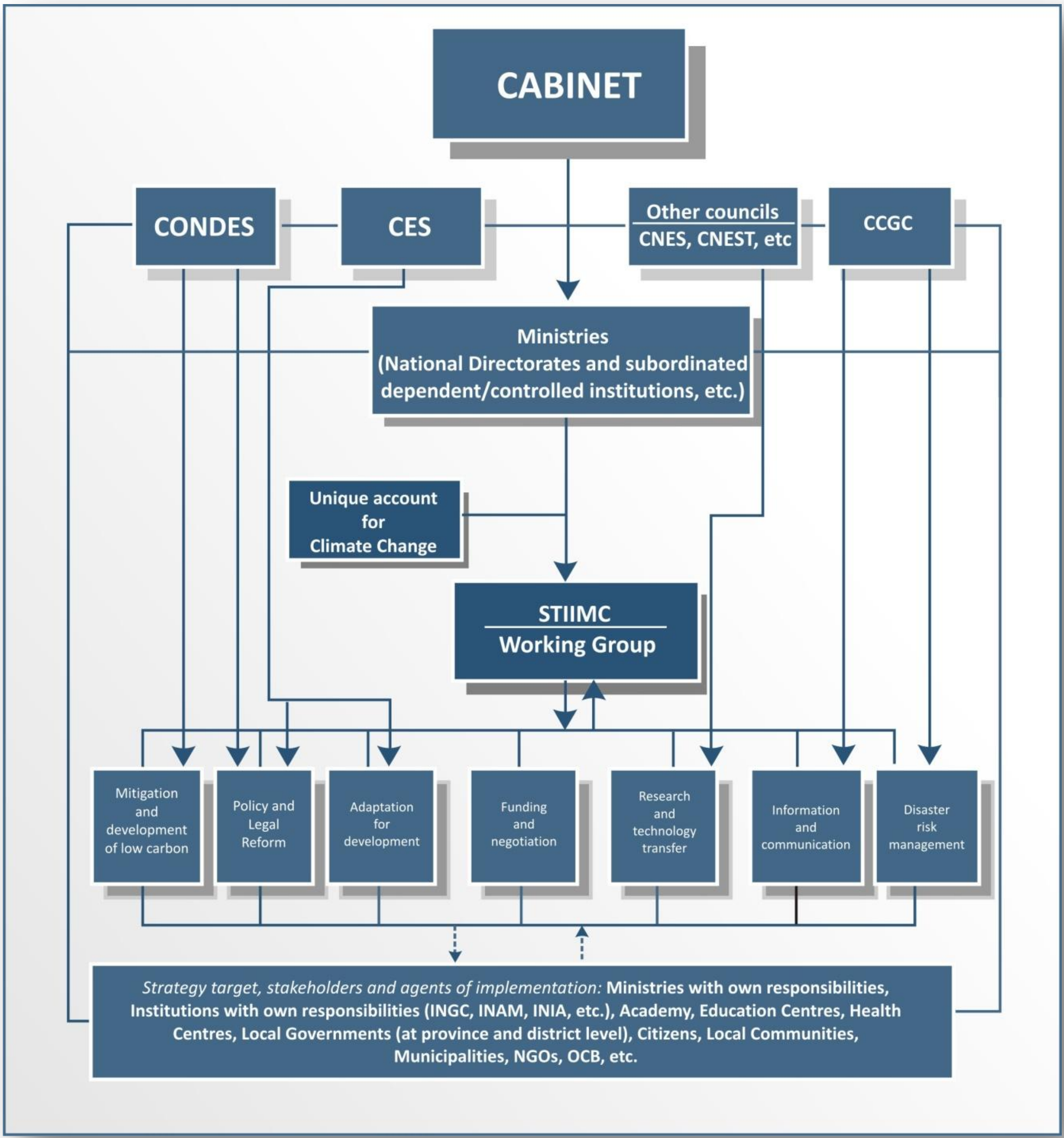


Figure 1: Proposal for institutional and financial arrangements for dealing with climate change

Proposed communication, supervisory and financial structure of the national strategy on climate change in Mozambique

The Council of Ministers, in its capacity as the coordinator of economic and social activities, would provide strategic and political guidance on the implementation process. The consultation and coordination bodies of the Council of Ministers (CONDES, CCGC, CES, CNES and CNCT) would continue, each in its own sphere, to produce consensus and advice for the Council of Ministers on the best ways of implementing and financing activities and of introducing reform at policy and legal levels. Each would, for its pillar, coordinate the process of the implementation of the national strategy. The ministries would follow with their national directorates and institutions, including those with specific functions, such as the INGC or INAM.

The coordination of implementation and funding would be undertaken by the STIIMC, consisting of national directors and other senior officials of the ministries and key institutions, such as the INGC, INIA and INAM. The STIIMC would be chaired by a member of the Government (the minister responsible for the environmental sector) and assisted by two vice-presidents, the director-general of the INGC and a national director from the MPD. To give it wider scope, the STIIMC would have, as permanent guests, representatives from the academy, the private sector and civil society. For specific topics, the STIIMC would have, as special guests, community representatives and development partners in Mozambique. The STIIMC would work with a dedicated account for climate change based in the MPD or MF.

Each of the four pillars would represent a working group within the STIIMC, with the cross-cutting working group represented in several. The working groups would be coordinated by a national director from the ministry with a leadership role in the pillar.

3: PILLAR II:
CAPACITY-BUILDING AND AWARENESS

"Education is the most powerful weapon which you can use to change the world." – Nelson Mandela[9]

The components of capacity-building and awareness creation are organised around the establishment of a centre of knowledge on climate change, with the overall vision of strengthening the capacity of Mozambicans to deal with the risks and opportunities presented by climate change.

Figure 2 summarises the mission and key goals of such a centre of knowledge on climate change.

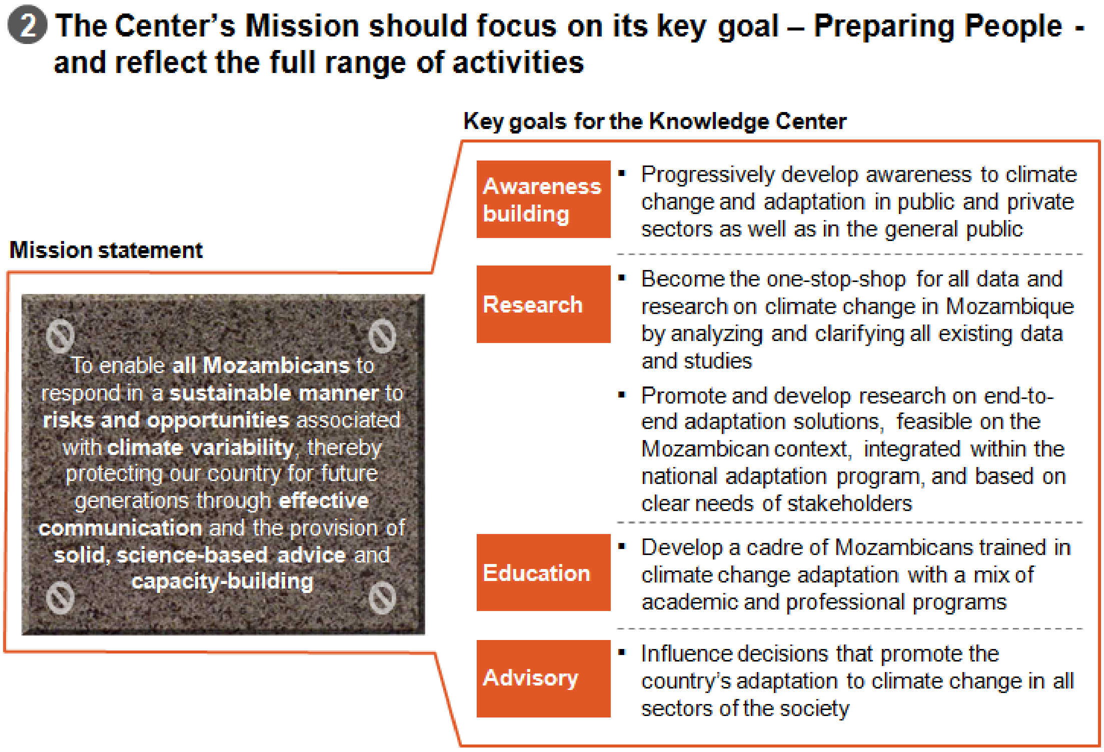


Figure 2: Mission and key goals for the Centre of Knowledge on Climate Change

The demands of addressing climate change are such that officials and policy-makers must constantly learn and retain information about an enormous range of topics and issues, which undergo rapid change. The only way in which they can do this is to rely on concise, clear, reliable information from various sources. A centre of knowledge on climate change would provide this information in an organised manner, answer questions from all user groups, undertake research and provide training programmes.

[9] Nelson Mandela Centre of Memory, South Africa. 2003. Available: http://db.nelsonmandela.org/speeches/pub_view.asp?pg=item&ItemID=NMS909&txtstr=education%20is%20the%20most%20powerful.

Figure 3 shows the key design features of such a centre of knowledge on climate change, obtained through wide stakeholder consultation, as detailed in the main INGC Phase II report.

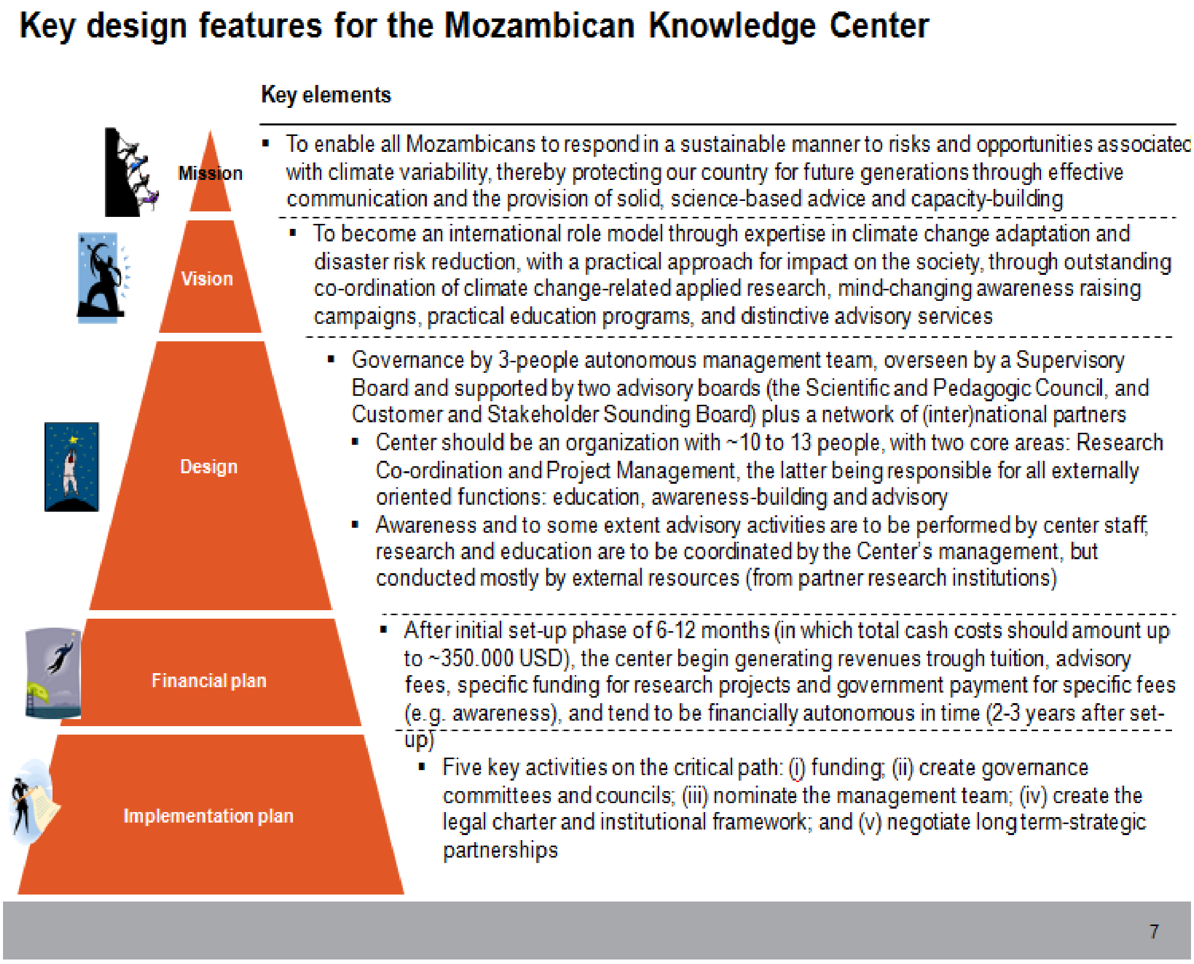
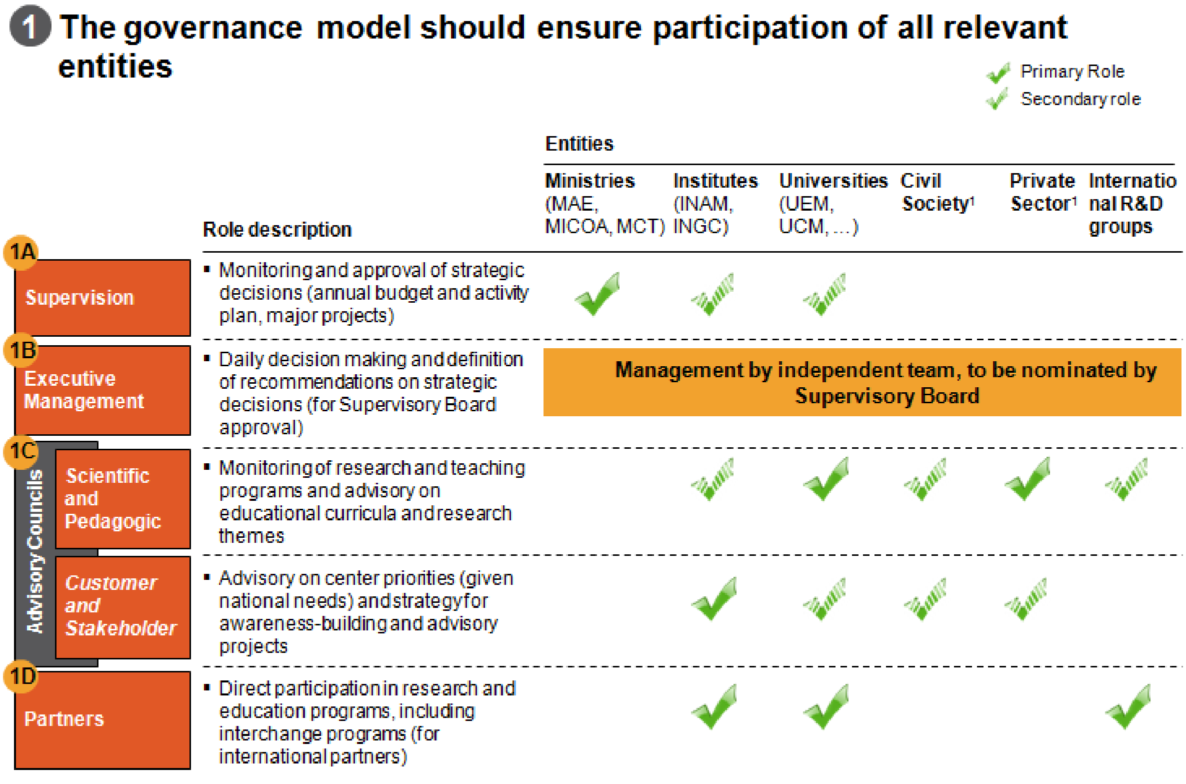


Figure 3: Blueprint for the Centre of Knowledge on Climate Change

Figure 4 summarises the proposed governance structure. Stakeholder consultation and best-practice analysis provided input into the envisioning of the centre of knowledge on climate change as an autonomous and independent centre to ensure adequate performance over cross-disciplinary and cross-functional activities. To enable a quick start-up and reduce costs in the short term, stakeholder consensus was reached at the technical level that the centre should be hosted by the President of the Academy of Sciences of Mozambique under the tutelage of the Minister of Science and Technology. The independence of the centre, in line with its terms of reference and best practices, would be safeguarded with the enrolment of independent heads of science and services and with the setting up of the proposed governance team. Institutions such as the INGC, INAM, the Ministry of Coordination of Environmental Affairs (MICOA), the Ministry of Agriculture (MINAG), the National Directorate of Water (DNA) in the Ministry of Public Works and Housing would all be considered clients of the centre. In terms of physical premises, the hub-and-spoke model was preferred, with a lean, central office in Maputo and three additional teams in different provinces.

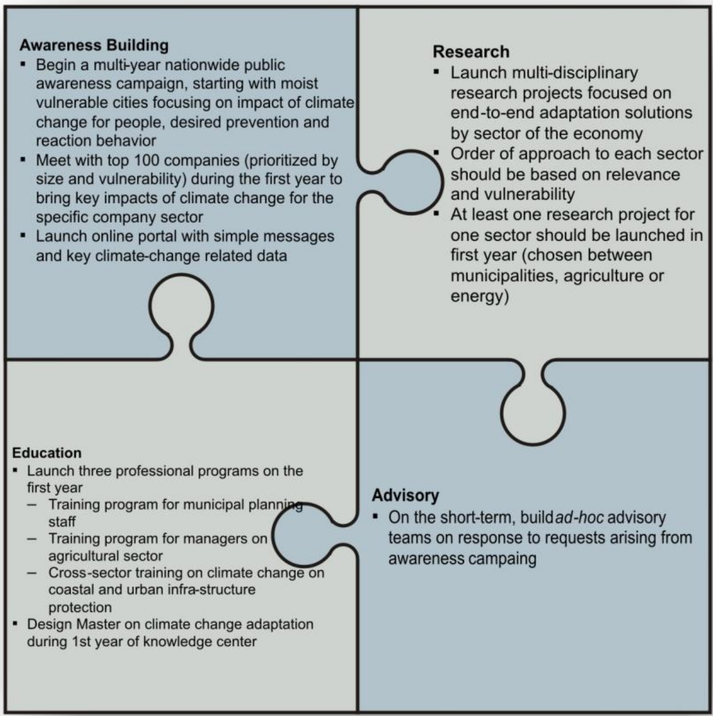


1 Through nominated representatives

Figure 4: Governance model for the Centre of Knowledge on Climate Change

The Supervisory Board (1A) would be the core body in overseeing the activities of such a centre of knowledge on climate change, meeting twice a year. The Executive Management team (1B) would be independent and staffed with high-performing individuals in their fields. The Advisory Councils (1C) would support the centre's activity and planning processes with technical counsel.

The centre of knowledge on climate change would have the following four goals: awareness raising; scientific research; education and training; and advisory services. Short and long-term activities have been defined for each of these goals in order to reach clear, measurable targets, as outlined in Figure 5. Three training modules have been worked out, which, once the centre of knowledge on climate change is legally established, could be among the first activities to start.



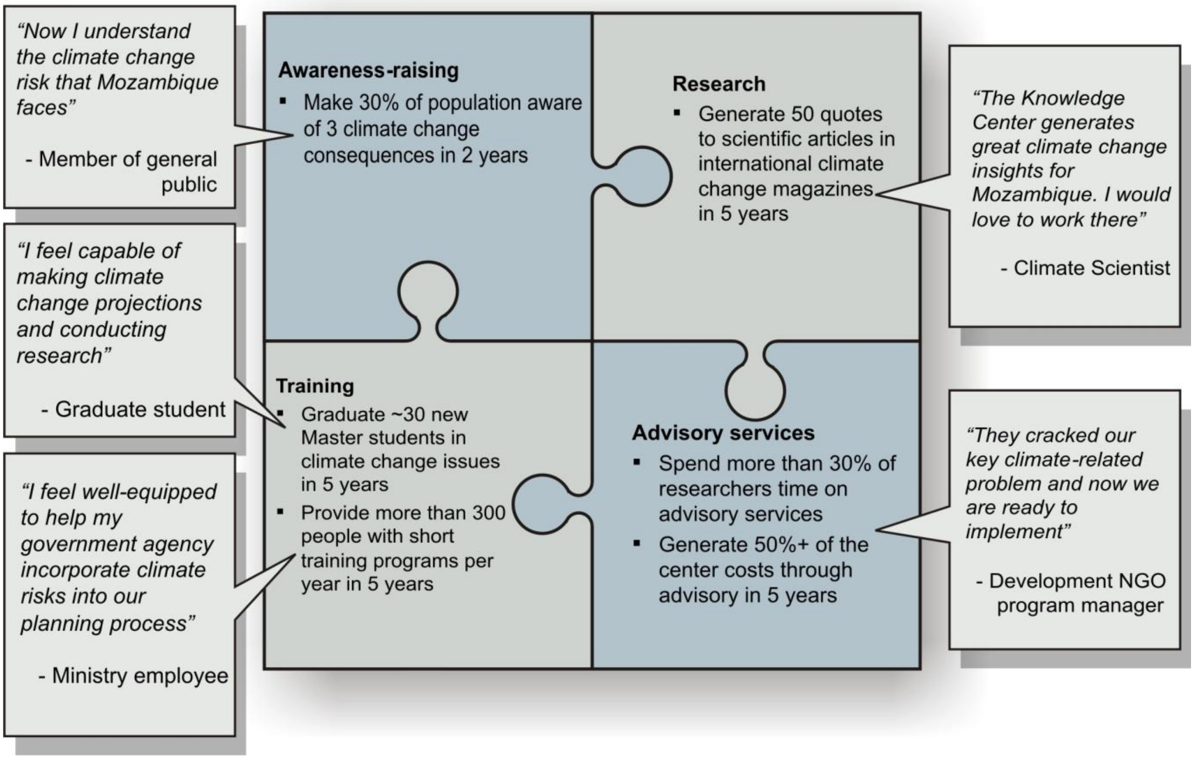


Figure 5: Short-term activities and clear, measurable targets set for each of the four goals of the Centre of Knowledge on Climate Change

In terms of the financial structure, the centre of knowledge on climate change would be designed in such a way as to guarantee its financial viability with minimal government or donor support, while, at the same time, guaranteeing high-quality performance. The key principle to achieving this financial autonomy would be to develop a flexible structure, with funding decided on a project-by-project basis and with projects being developed leveraging on external staff from partner institutions. Naturally, in the start-up and build-up phases, financial autonomy would not be entirely possible. As a result, after an initial set-up phase funded by generic sources, the centre should become financially sustainable with project funding and direct revenues from services within the space of three years. Figure 6 shows the pro forma profit-and-loss (P&L) statement, with the first stable year in 2014 based on a certain scenario of annual activities by the centre.

Proforma P&L Statement

ESTIMATES

P&L Statement (thousand USD)	2012	2013	2014	2015	2016
Revenues					
Project Specific Funding					
Research	~30	~188	~400	~430	~430
Awareness	~60	~258	~310	~310	~310
Direct Revenues					
Tuition	~15	~120	~308	~330	~330
Advisory Fees	~33	~198	~410	~440	~440
Generic Funding	~205	~400	~75	~0	~0
TOTAL REVENUES	**~343**	**~1.163**	**~1.503**	**~1.510**	**~1.510**
Costs					
Personnel Costs	~140	~400	~403	~410	~410
Rent, utilities and equipment	~45	~100	~100	~100	~100
Project-related costs (travel, etc.)	~30	~130	~160	~160	~160
External staff	~105	~525	~840	~840	~840
Other setup costs	~23	~8	~0	~0	~0
TOTAL COSTS	**~343**	**~1.163**	**~1.503**	**~1.510**	**~1.510**
NET PROFIT/LOSS	**~0**	**~0**	**~0**	**~0**	**~0**

Figure 6: P&L statement for the Centre of Knowledge on Climate Change, based on a scenario by the second year, of four large and six small research projects, four advisory studies and 1 000 people attending professional programmes

A slower evolution scenario would lead to a downward adjustment of the P&L statement and a later first stable year.

Underlying all the activities of the centre of knowledge on climate change would be a web-based information portal and a GeoNode site[10], which would make all metadata and outputs of the INGC climate change projects of Phases I and II and of the future Phase III accessible and provide tools for data sharing (Figure 7). Different user groups (such as scientists and the private sector but also children) would have different access levels, depending on their needs. Key early-warning staff would have access to an interactive decision support system that, for example, simulates river discharge based on climate change and upstream development scenarios and that contains flood hazard analysis, and vulnerability and impact mapping.

[10] Designed and established in INGC Phase II by the World Bank Open Data for Resilience Initiative.

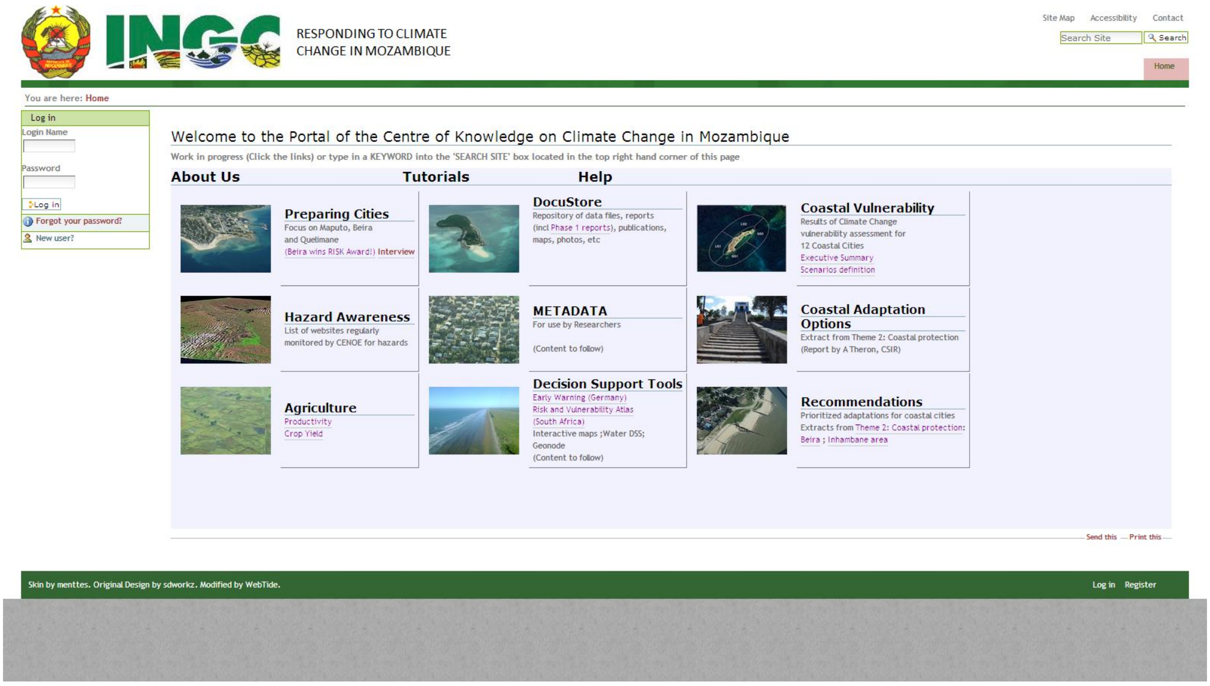


Figure 7: *Information portal for the Centre of Knowledge on Climate Change on disaster risk reduction and climate change adaptation accessible to the public and other user groups, with varying levels of authorisation*

Storylines were developed through the Google Earth platform to help guide viewers through project results, from understanding climate risks and vulnerability to identifying adaptation measures and mainstreaming response. The site aims to promote broad collaboration among institutions and integrate various information initiatives. The branding of the site will change when its management is taken over by the centre of knowledge on climate change. The portal is still in draft form and should be publicised in the third quarter of 2012.

Box 1: The Centre of Knowledge on Climate Change would provide easy access to climate change information and answers to key questions for all interested parties. The following are some examples of such key questions:

- What is the projected impact of climate change on Northern, Central and Southern Mozambique by 2030 and 2060 in terms of water availability, agriculture, floods, droughts, cyclones and sea-level rise?

- What are the threats to food production and what are the solutions?
- Do we continue to encourage drought-resistant crop development in, for example, the Limpopo area? Where else should we encourage this? Given climate change, do our agricultural plans still make sense?
- Given our population growth and increasing demands on land and water, how can we increase agricultural yields under conditions of less water availability, more saline intrusion, higher temperatures, unpredictable rainfall, less fertile soils and more erosion?

- How do we protect this part of the coast? What do we add to our provincial and municipal planning? Where are we most at risk in our city? What is the magnitude of the problem?
- What can we do now to protect our city and citizens? What standards should we apply?
- What should we do in the next five years to protect our city and develop opportunities?
- If three to four events occur simultaneously, what (additional) early-warning and response mechanisms should be in place to deal with them? How can we better forecast such events?

- How do we know if our investment is safe? What is the needed investment to ensure adaptation to climate change in priority high-risk, high-impact areas and what role can the private sector play in this investment? How does the (co-) financing of adaptation measures help private-sector companies to achieve their strategic aims? What are the barriers to sustainable investment and how can the Government of Mozambique facilitate such investment?

- Where do we want to be in 10 years' time in terms of protecting Mozambique against climate change and benefiting from opportunities that this creates? What should be the main pillars and plans on which response to climate change should be based? How can we encourage sustainable investment in Mozambique (in the north, the south and the centre) to ensure adaptation to climate change? How do we inform and prepare people at community level for future climate change? What are their questions and concerns? What performance measures should we put in place for all these adaptation measures? How can we avoid skills, information and facilities being lost through over-dependence on single individuals and disorganised databases scattered across spatially separated institutions?

- If I have a question related to climate change in Mozambique, where do I go? How do I know what other countries are doing to prepare for this type of risk? What is Mozambique doing in terms of, for example, research, adaptation and policies? What is the Government of Mozambique doing?
- If I want to learn how I can incorporate climate change risks into my planning, where do I go?
- If I want to include climate change in my studies and career, where do I go?

4: PILLAR III: IMPLEMENTATION OF ADAPTATION

The third pillar of INGC Phase II project concerns the identification and costing of priority adaptation options in high-risk, high-impact areas so that implementation can start as soon as funding is made available by the international community and the Government of Mozambique. The sections that follow outline five specific themes: key adaptation measures for *coastal protection* (III a); the economic rationale for the immediate start of *preparing cities* (III b) for climate change; key adaptation measures for both *water* (III c) and agriculture (*food security*) (III d); and the potential of *engaging the private sector* (III e) in climate change adaptation in Mozambique.

Figure 8: Nacala area, 2011: Example of infrastructure at high risk of coastal climate change impacts

4.1 THEME III A: COASTAL PROTECTION

"It is not only for what we do that we are held responsible, but also for what we do not do." – Molière

Mozambique's coastal zone is particularly vulnerable to the expected impacts of climate change because of its vast low-lying coastal plains with deltas and soft, erodible sections, its high population concentrations in close proximity to the sea, its poverty, its low capacity to defend infrastructure, its inadequate and ageing coastal defences and its susceptibility to cyclone activity. The combination of extreme events, in other words, sea storms occurring during high tides in conjunction with sea-level rise (SLR), will have by far the greatest impacts on disaster risk in Mozambique and will be the events that will increasingly overwhelm existing infrastructure (Theron *et al*., 2010). In Mozambique, some 7.7 million people live in coastal districts[11].

The most important drivers of risk to coastal erosion and flooding are waves, tides, SLR and increased storminess. Based on the assessment of these drivers, hazards and impacts (INGC Phase II, 2012), it is expected that the increase in disaster risk along the coastline will occur progressively. The consequences of the impacts are, however, expected to increase exponentially.

The coastal protection study determined the levels of coastal vulnerability of and the potential impacts of SLR and more extreme weather events on the following 11 high-risk cities and towns along the coast: Ponta d'Ouro; Maputo/Matola; Xai-Xai beach; Tofu/Barra; Maxixe/Inhambane; Vilankulos; Beira; Quelimane; Ilha de Mozambique; Nacala; and Pemba. Specific implications for tourism and industry in each of the 11 locations were identified and recommendations were given on the interventions needed to protect people and infrastructure from the increasingly extreme weather events and SLR.

Given its potential implications for Mozambique's coastal plans and investments, the INGC Phase II coastal protection study was peer reviewed by national and international experts in an exercise led by the Academy of Sciences of Mozambique.

SLR and coastal flooding scenarios

In order to quantify hazards and find ways of reducing risks and deriving practical adaptation measures, it is necessary to forecast the coastal response and severity of impacts. To this end and given the lack of historical data and information along the Mozambican coastline, three scenarios were defined to establish the hazard levels at specific sites in terms of possible flooding due to

- extreme inshore sea-water levels, resulting in the flooding and inundation of low-lying areas,
- changes in cyclone characteristics, winds and wave regimes, resulting in direct wave impacts,
- the coastal erosion and under-scouring of, for example, the foundations of structures located at the sea front,
- system complexities, thresholds and non-linearities related to, for example, sand transport and

[11] *Source*: INE. In 2007, 6,969,754 people lived in coastal districts: 3,036,787 in the South (63% of the provinces' population); 2,052,638 in the Center (37% of the provinces' population); 1,880,329 in the North (34% of the provinces' population). Assuming an annual population growth of 2%, by 2012 the total population living in coastal districts will be approximately 7,695,170.

- a combination of extreme events, such as sea storms during high tides plus SLR.

The three SLR scenarios are detailed in Annex 1, as are the consequences for the cities of Maputo, Beira and Pemba in terms of the vulnerability of infrastructure situated below certain elevation levels (+5 m, +8 m and +10 m relative to mean sea level [MSL]).

The implications of the low, medium and high SLR scenarios were mapped for the cities and towns in the 11 areas shown in Figure 9 to obtain first-level identification of the low, medium and high hazard areas in these cities. Figure 9 shows that virtually all areas (from sheltered to exposed locations) below the +5 m contour in these cities are already at risk from the low flooding scenario.

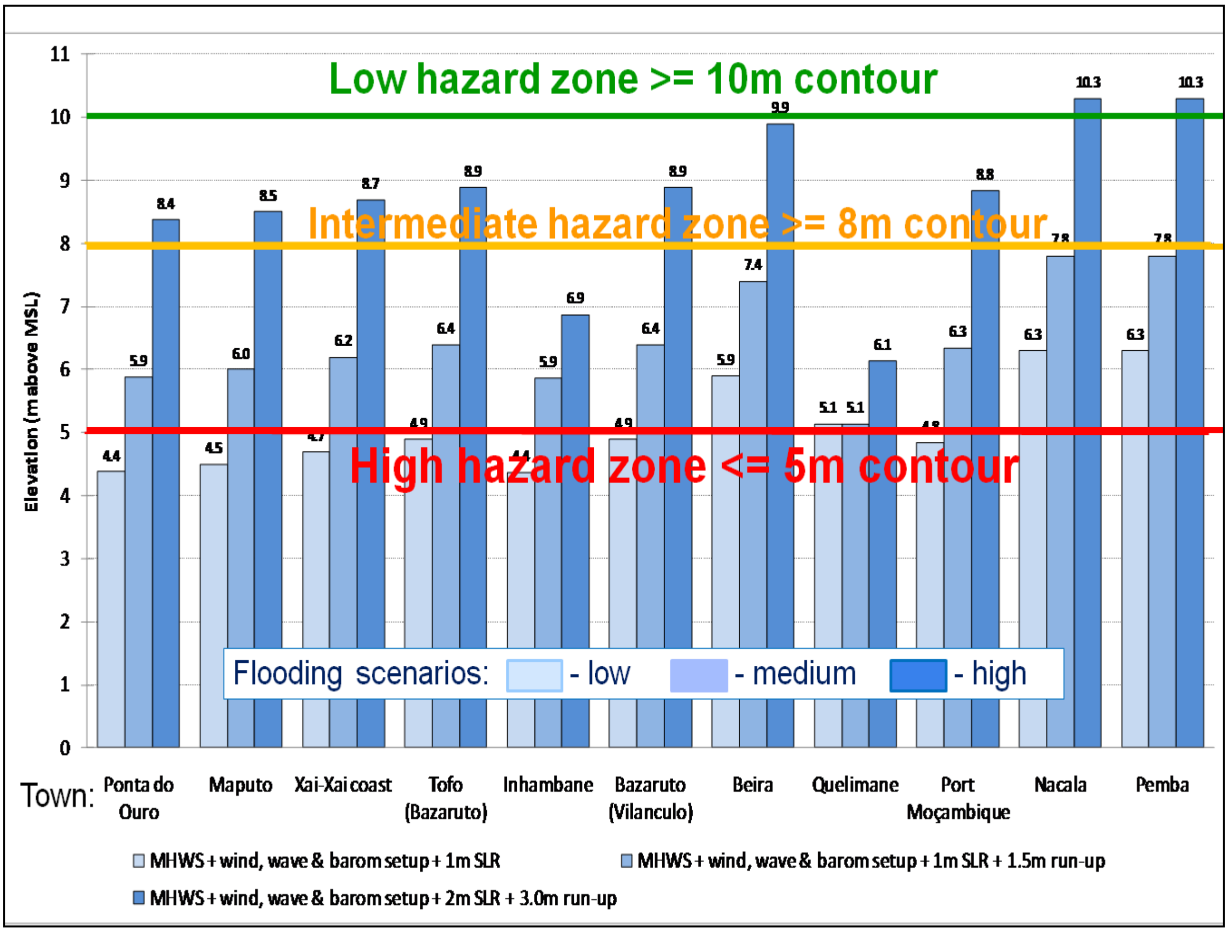


Figure 9: Low, medium and high SLR scenarios

As can be seen from Figure 9, three contour lines – +5 m, +8 m and +10 m – relative to MSL derived from satellite imagery are roughly associated with the three flooding (SLR) scenarios for each city or town.

Infrastructure and people located in exposed (unsheltered) areas between the +8 m and +10 m contour (elevation) lines are generally vulnerable only in the high (worst case) SLR scenario of mean high-water spring (MHWS) plus a wind, wave and atmospheric set up (a total of 2 m) of a +3 m wave run-up and a +2 m SLR.

Infrastructure and people located in areas between the +5 m and +8 m contour lines are only semi-exposed to direct wave impact but are still vulnerable in the best estimate (most likely) scenario of MHWS plus a wind, wave and atmospheric set up of a +1.5 m wave run-up and a 1 m SLR by 2100 (or a 0.3 m to 0.5 m SLR by 2050).

Infrastructure and people located in areas below the +5 m contour line are already highly vulnerable to extreme events during MHWS and with the low (best case) scenario of 0.5 m SLR by 2100, even without considering wave run-up.

Box 2: SLR global trends

A comparison of minimum and maximum estimates of global SLR by 2100 shows that, while the 2007 IPPC fourth assessment report predicts an approximate 0.4 m SLR by 2100, post-2007 studies (Milne *et al*., 2009; Nicholls & Cazenave, 2010; Pfeffer *et al*., 2008; SWIPA, 2011) give an overall range of an approximate +0.5 m to +2 m SLR by 2100, as also found in various reviews (Fletcher, 2009; Theron & Rossouw, 2009).

The increased melting and breaking up of the ice shelf in Greenland and the West Antarctic are red flags suggesting that actual changes in sea level are tracking the upper-limit accelerating sea-level scenarios and need to be taken seriously.

It is therefore concluded that the best estimate (mid-scenario) for SLR by 2100 is around +1 m, with a plausible worst case scenario of +2 m and a best case scenario of +0.5 m. The corresponding best estimate (mid-scenario) projection for 2050 is a +0.3 m to +0.5 m SLR.

Coastal vulnerability index

To determine the most vulnerable sections along the Mozambican coast to flooding and inundation, a first-level assessment was conducted for the entire Mozambican coastline based on the following nine parameters: topographic elevation; distance to urban infrastructure; geology; geomorphology; land cover; tidal range; maximum offshore wave height (National Centers for Environmental Prediction); erosion and accretion; and cyclone occurrence. Coastal points were defined along the entire Mozambican coast at 1 km intervals and the results were recorded at these intervals.

A more detailed vulnerability index was drawn up and an assessment was done for 11 selected areas at approximately 10 points over a stretch of approximately 10 km per site based on a comprehensive set of 14 hazard drivers and vulnerability indicators. The potential effect of different scenarios (in other words, with an SLR of +0.5 m, +1 m and +2 m, with or without cyclones and with or without increased storminess or wave run-up) on each of the 14 vulnerability indicators was assessed for each shoreline location point. Annex 3 summarises the 14 vulnerability indicators and the different scenarios.

The INGC Phase II report on coastal protection provides the results for all the cities and towns in the 11 areas. It is concerning to note that almost all the points at the study sites are rated as having from medium or yellow vulnerability (for the present case and low SLR scenarios A1 to B4 [Figure 10A]) to some very high vulnerability (for the high SLR scenarios D3 and D4 [Figure 10C]).

Figure 10A, Figure 10B and Figure 10C show the vulnerability ratings for Beira. The analysis shows which sections of this part of Beira's coastline are the most vulnerable and how vulnerability changes with the different SLR scenarios.

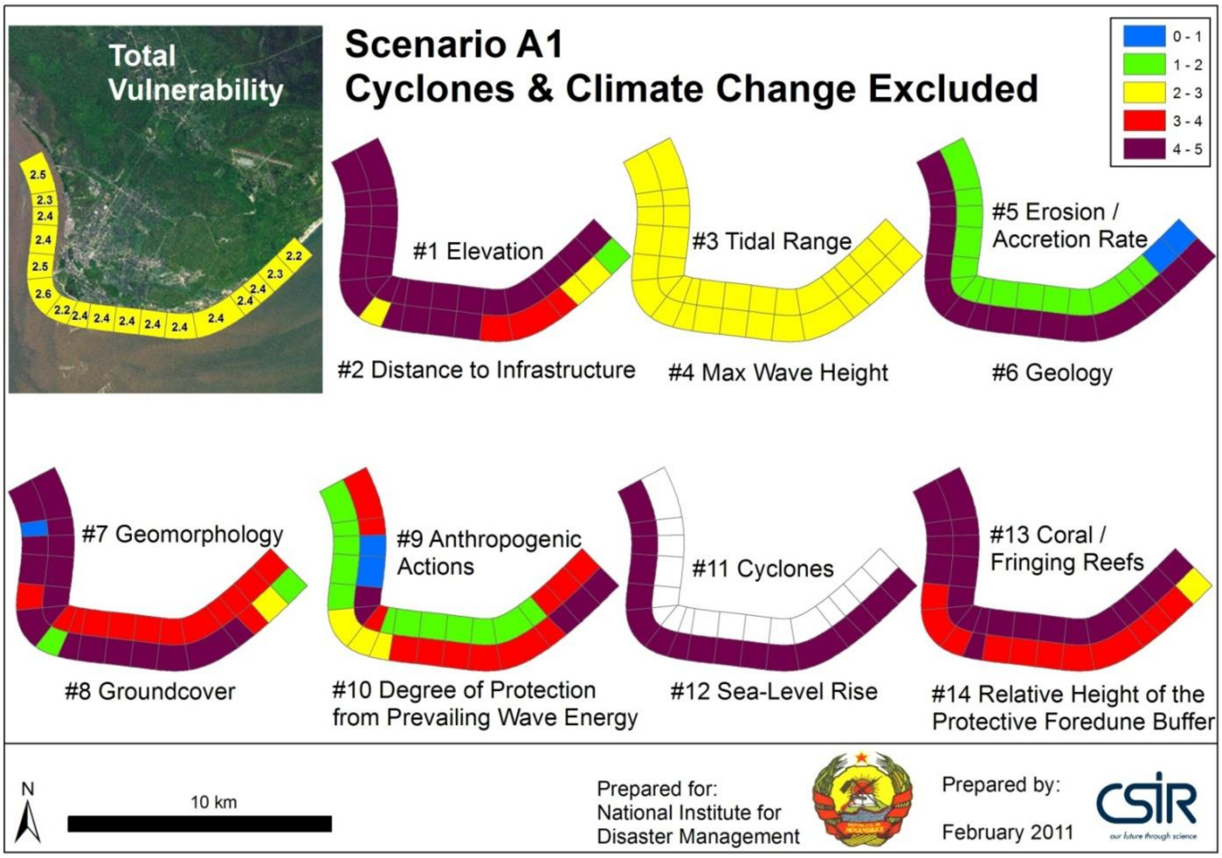


Figure 10A: Beira coastal section (17 measuring points, 17 km): Vulnerability rating for scenario A, i.e. no climate change and no cyclones, for each of 14 parameters

As can be seen from Figure 10A, the total average vulnerability of all 14 parameters combined (top left corner) for Beira today is yellow (medium, category 2 to 3). Vulnerability as measured by individual criteria, such as elevation, ground cover and the height of protective buffers, is already very high.

Vulnerability is measured on a scale of 1 to 5, with 1 being the lowest vulnerability (blue) and 5 being the highest vulnerability (purple).

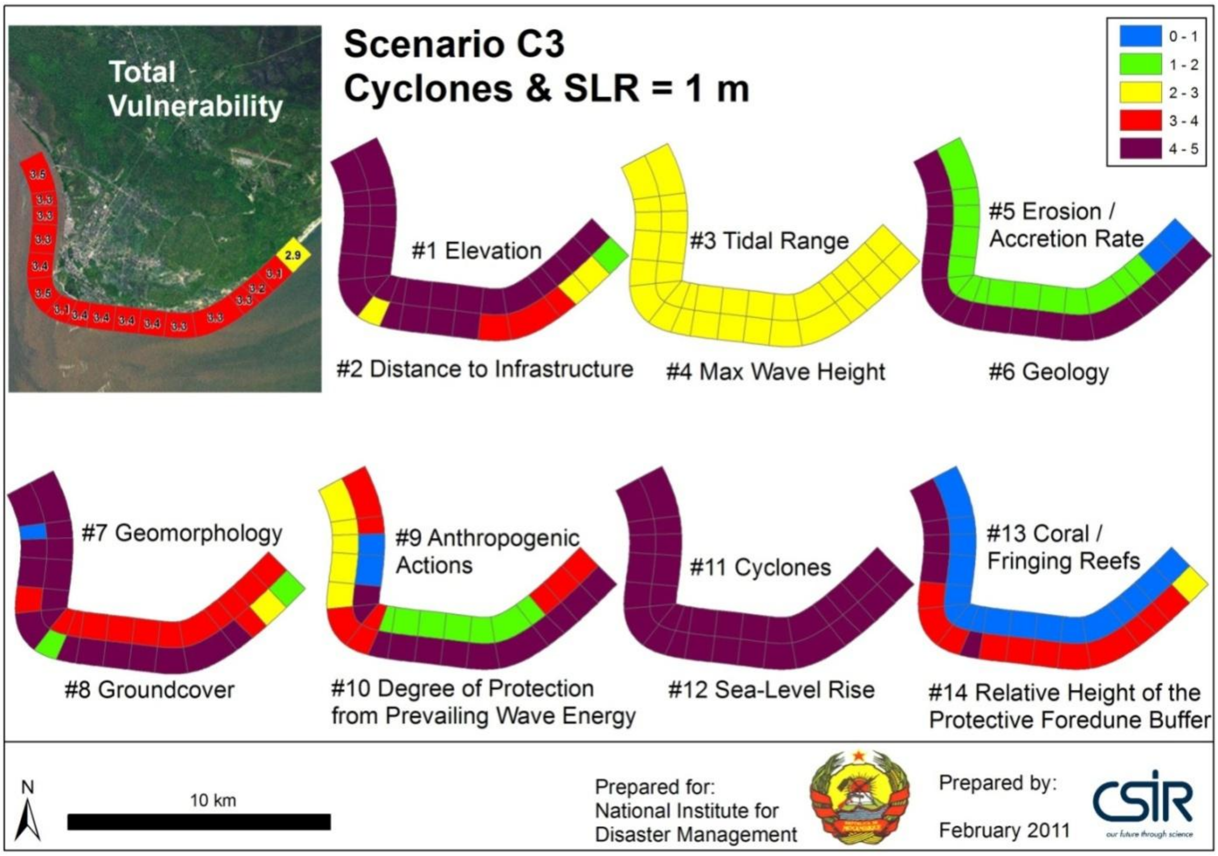


Figure 10B: Beira coastal section (17 measuring points, 17 km): Vulnerability rating for the best estimate SLR scenario C3, i.e. a +0.3 m to +0.5 m SLR by 2050 or a +1 m SLR by 2100 plus cyclones and a +1.5 m wave run-up.

The analysis shows the level of vulnerability of each section of this part of the coast for each of 14 parameters and how vulnerability increases compared to no climate change (Figure 10A).

As can be seen from Figure 10B, the overall vulnerability of all 14 parameters combined (top left corner) for Beira increases to red under scenario C3.

Vulnerability is measured on a scale of 1 to 5, with 1 being the lowest vulnerability (blue) and 5 being the highest vulnerability (purple).

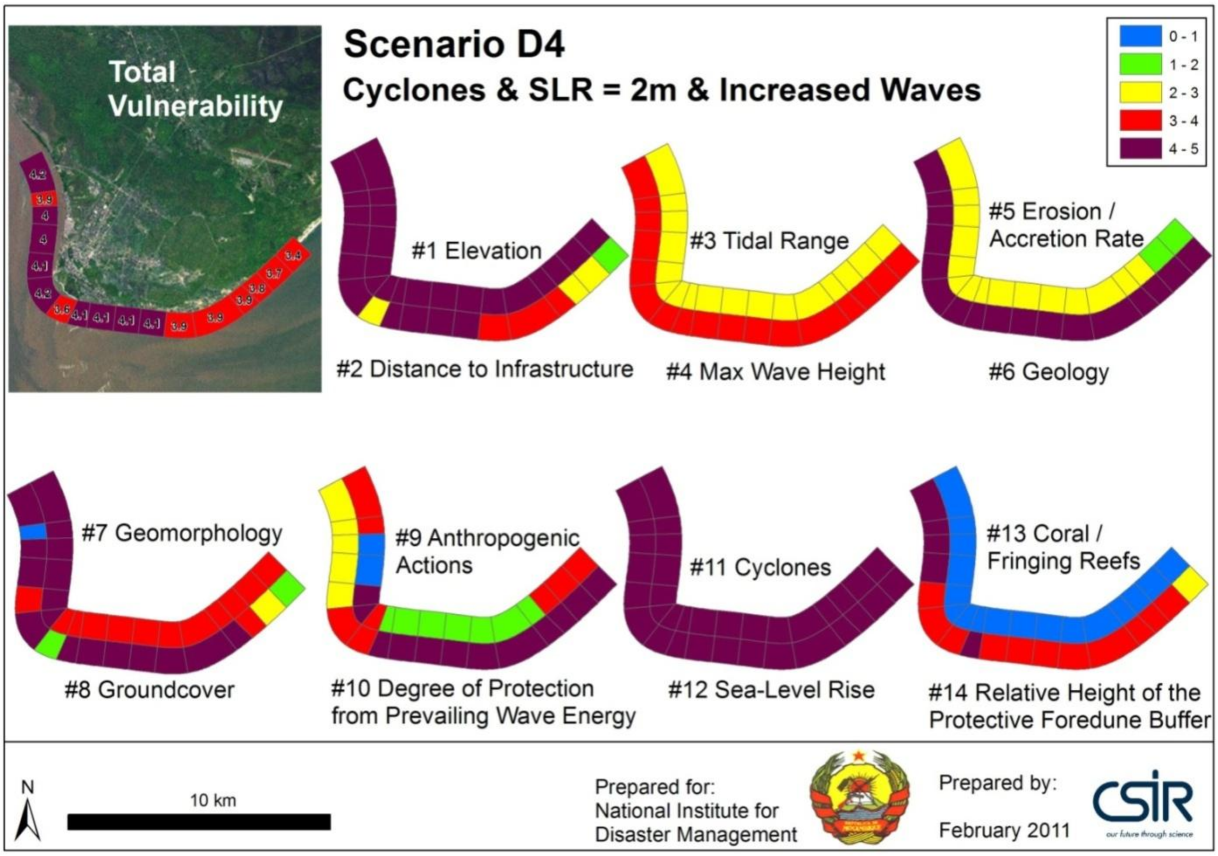


Figure 10C: Beira coastal section (17 measuring points, 17 km): Vulnerability rating for the worst case SLR scenario D4, i.e. a 1 m SLR by 2050 or a 2 m SLR by 2100 plus cyclones and 3 m wave run-up

As can be seen from Figure 10C, the overall vulnerability of all 14 parameters combined (top left corner) for Beira increases to purple and red under scenario D4.

Vulnerability is measured on a scale of 1 to 5, with 1 being the lowest vulnerability (blue) and 5 being the highest vulnerability (purple).

Figure 11 shows the vulnerability comparison for the 12 cities and towns under the most likely SLR scenario plus cyclones and an increase in storminess (scenario C4).

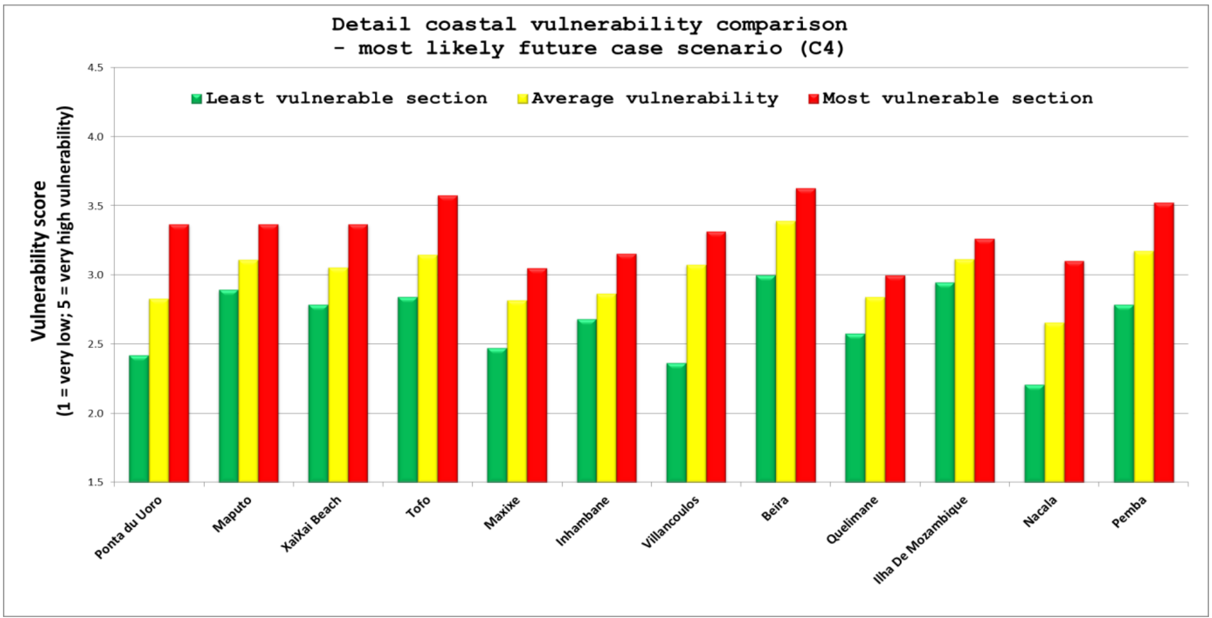


Figure 11: Comparison of the vulnerabilities of 12 towns and cities for the most likely future case scenario C4, i.e. a 30 m to 50 cm SLR by 2050 or a 1 m SLR by 2100 plus cyclones and increased storminess

As can be seen from Figure 11, the most vulnerable city is Beira, followed by Tofu, Pemba, Xai-Xai beach, Maputo, Ponta d'Ouro and Vilanculos. The least vulnerable towns are generally Maxixe, Quelimane and Nacala. As indicated by the yellow bars, some of the towns will, on average, be highly vulnerable (with a score of 3 to 4) to the impact of climate change, while, as indicated by the red bars, every town will have at least some location that is highly vulnerable to the impact of climate change.

Priority coastal adaptation measures

A comprehensive literature review led to the identification of a number of management options and soft and hard coastal engineering methods available to protect the shoreline. By considering the coastal processes and characteristics of the study area and the factors governing suitability for coastal development, various potential response options were identified for each of the studied cities and towns.

The examples in Figures 12 to 19 summarise the priority adaptation measures for the cities and towns of Beira, Maputo and Pemba. The complete description of each measure and the recommendations for Ponta d'Ouro, Xai-Xai beach, Tofu/Barra, Quelimane, Ilha de Mocambique, Maxixe/Inhambane, Vilanculos and Nacala are contained in the INGC Phase II report on coastal protection.

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Figure 12: Beira: Estimated contours (+5 m, +8 m and +10 m to MSL)

As can be seen from Figure 12, without intervention, most of Beira is already at extreme risk of flooding and only the high area a few kilometres inland to the north would really be at low risk. Where possible, new developments should therefore be located above the +8 m MSL level to offer protection against a combination of a cyclone at spring tide (with a +4.9 m MSL reach) with wave run-up of +1.5 m at a +1 m SLR. In the absence of appropriate adaptation measures, critical infrastructure should be built above the +10 m MSL level.

The main considerations in choosing between the options are effectiveness in adapting to expected climate change impacts, environmental aspects, costs and, possibly, whether an option has a dual purpose in also addressing possible existing background coastal erosion problems. Impaired beach (and possible inter-tidal rocky area) usage and aesthetic impacts should also be assessed.

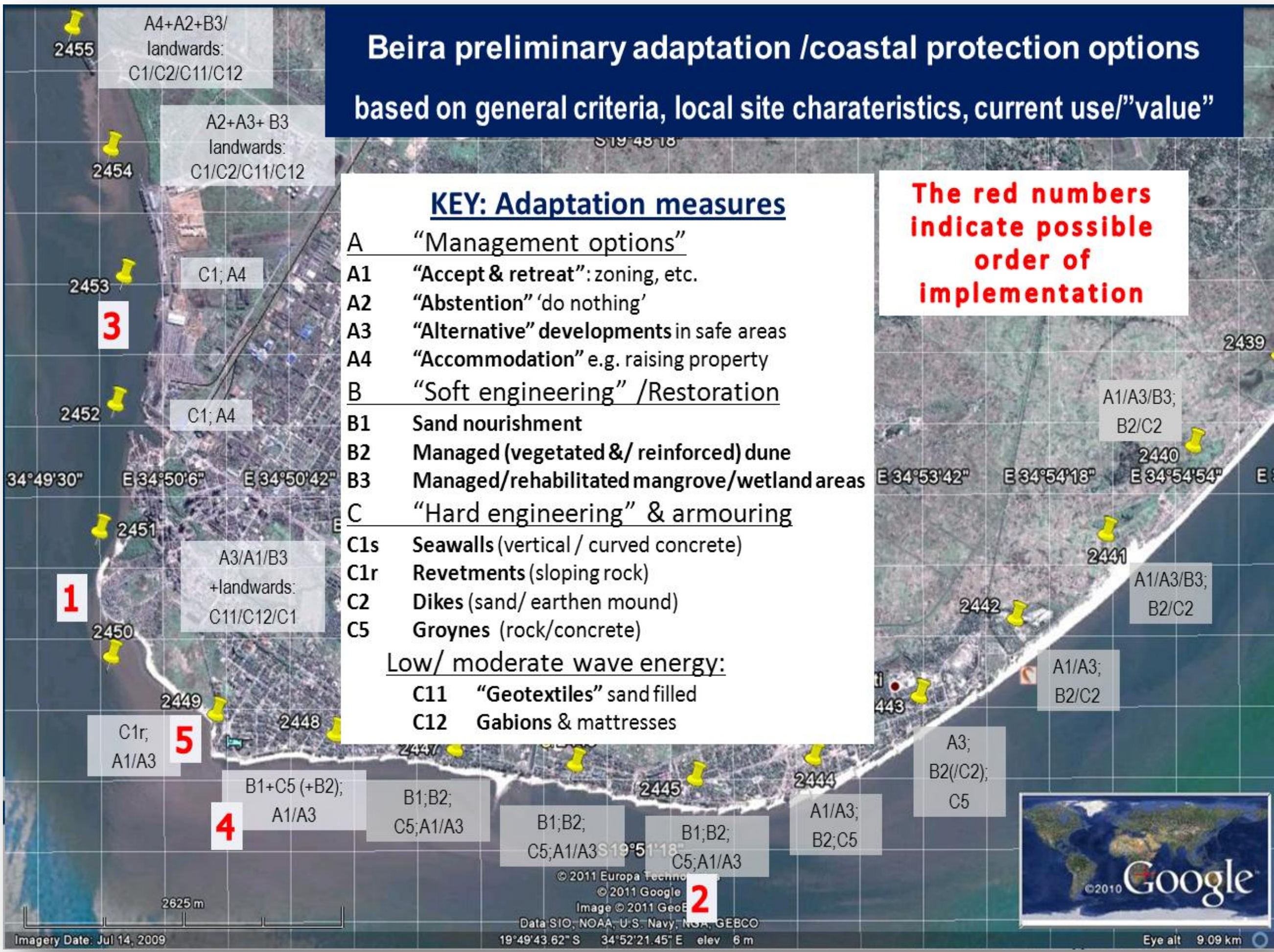


Figure 13: *Beira: Coastal adaptation plan summarising the preferred adaptation options along each 0.5 km section of the western, southern and south-eastern Beira coast*

As can be seen from Figure 13, the red numbers indicate the suggested order of priority. The measures found to be most appropriate include four management options (labelled A1 to A4), three soft-engineering or restoration measures (B1, B2 and B3), four hard-engineering and armouring options (C1s, C1r, C2 and C5) and two options more suitable for low to moderate wave energy sites (C11 and C12).

Box 3: Sea ports

By their nature, ports are located as close to the water as possible and therefore often in low-lying areas. By recommending that ports, as national key infrastructure facilities and as having design lifespans extending from 50 to 100 years, be located above the +8.5 m MSL in Maputo and above the +10.0 m MSL in Beira, it means that, for example, the design of the foundation structure and layout should allow for the future heightening of the quays, wharfs and adjacent infrastructure. It does not mean that the ports should be relocated to higher areas, which would render them inoperable.

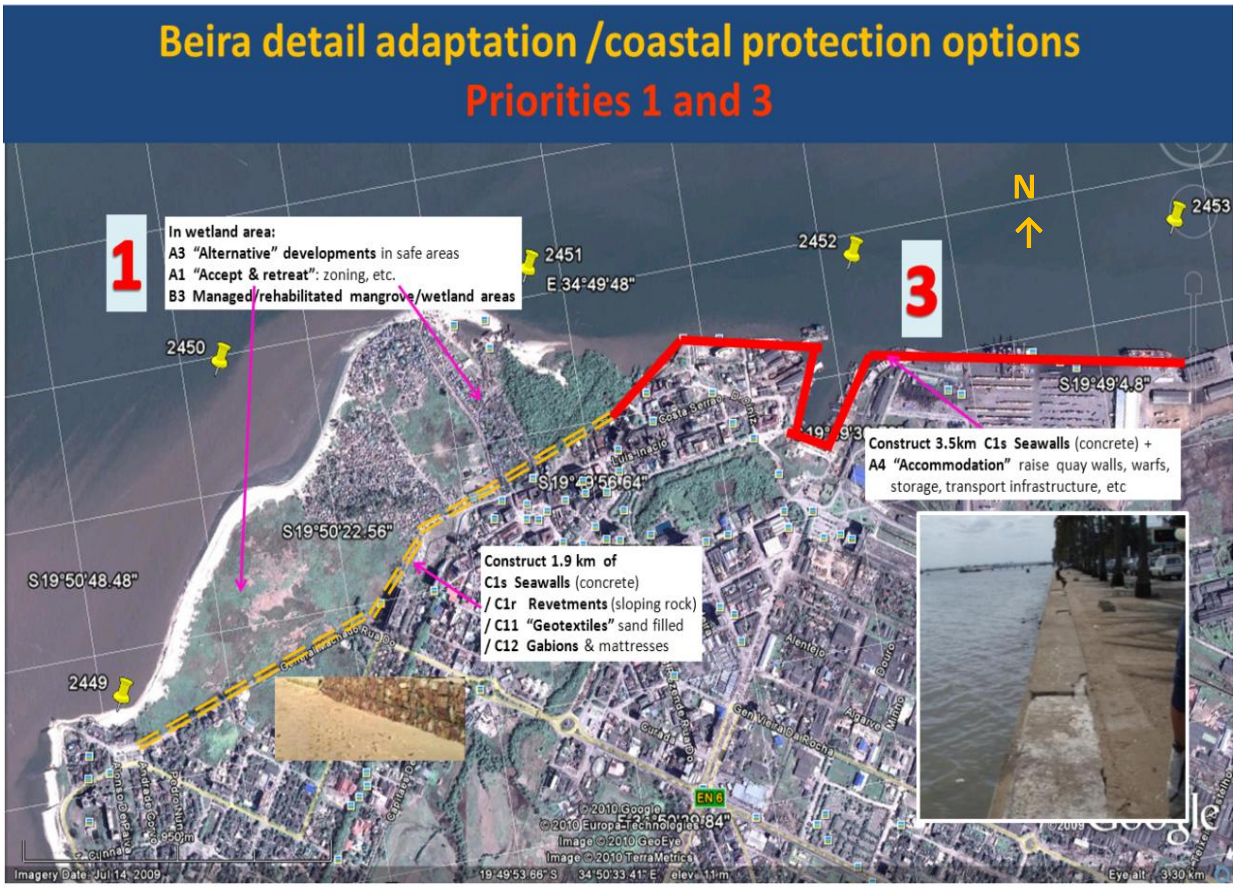


Figure 14: Western Beira: Adaptation and coastal protection options based on general criteria, local site characteristics and current use or value

As can be seen from Figure 14, the preferred option for the mangrove or wetland and informal settlement area between markers 2449 and 2451 (the Ponta Gea-Cabedelo area, marked as priority no. 1 for Beira) is (B3) management actions such as (A3) alternative developments in safe areas, zoning, and (A1) accept and retreat. The landward edge of this mangrove wetland area, as indicated by the dashed orange line, should eventually be protected preferably by a rock revetment (C1r) (or, potentially, by a concrete sea wall (C1s), if affordable)

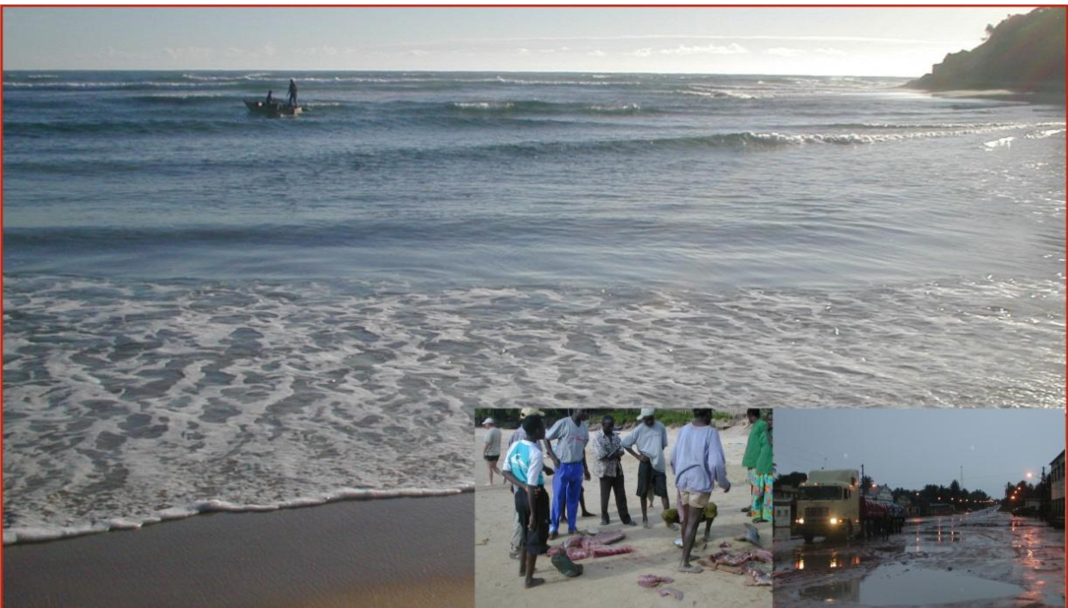
Existing infrastructure is already too low (in other words, it excludes SLR) and therefore needs to be upgraded and maintained as a matter of urgency. Quay walls, wharfs, storage areas, transport infrastructure etc. located in the vicinity of existing Beira port infrastructure (marked as priority no. 3 for Beira) will have to be raised in stages to an estimated level of at least +7.4 m MSL by 2100. This level will have to be revised at, for example, 10-year intervals, as more accurate SLR projections become available in the future. The protecting sea walls will have to be similarly raised, where possible, or new walls should be constructed.

One of the impacts of SLR is that waves will reach further inland than at present, which implies that *coastal development set-back lines* (of which few exist) must be defined or, where they exist, must be adjusted. A coastal development set-back line is the line landward of which fixed structures (such as houses and roads) can be built with reasonable safety against the physical impacts of coastal processes (such as sea storms, wave erosion and run-up). In other words, coastal set-back lines can be used to identify infrastructure located too close to the sea and therefore vulnerable to damage, allowing for the design of strengthening measures. In addition, coastal set-back lines will help to determine areas of low vulnerability, which will aid the design and location of new developments and infrastructure in low-risk areas.

Factors that co-determine the location of coastal set-back lines are storm wave run-up elevations and the extent of shoreline retreat due to erosion. The Mozambican coastline includes many sandy areas, which mostly have no hard protection and on which cyclone-generated waves could impact. This leads to a high potential for the erosion of these sandy coastlines. Wave run-up is also an important factor to take into consideration when determining set-back lines. During the 2007 storm in Kwazulu-Natal (on the South African east coast, located approximately 1 000 km south of Mozambique), for example, the maximum wave run-up was approximately 7 m as a result of wave heights of about 8.5 m. The coastline retreated by approximately 100 m in some locations due to coastal erosion caused by this storm. It was calculated that, in the event of a +1 m SLR, a wave height of 24% less than the 2007 Kwazulu-Natal storm would result in similar wave run-up elevations. This is alarming in that the return period of the 2007 event in terms of high wave run-up would effectively be subject to a six-fold reduction. In other words, statistically, such impacts are likely to occur six times as often in the long run due to an SLR of +1 m.

Wave run-up and erosion are, in turn, influenced by the amount of SLR that is expected, projected increases in storminess and the elevation (thus also location) of coastal areas in relation to sea-water flooding levels.

The cities of Maputo and Beira both contain extensive infrastructure and development within the coastal zone, which is potentially subject to climate change impact. For each city and for each of the SLR scenarios developed, an SLR coastal erosion model (Annex 2) was employed to quantify the potential erosion resulting from SLR.



An example of the calculated potential erosion and recommended set-back lines at several locations along the Beira shoreline is given in Table 3 below for the three SLR scenarios (of +0.5 m, +1 m and +2 m). A similar exercise was done for Maputo (contained in the INGC Phase II report on coastal protection).

Table 3: Example quantification of coastal erosion set-back lines for Beira for three SLR scenarios. Infrastructure located seaward of these set-back lines is considered too close to the sea and therefore vulnerable to damage.

GPS point (corresponding to yellow pins on maps in Fig. 13 and Fig. 14 above)	Beira set-back lines – summary		
	SLR (m)	Erosion due to SLR (m)	Erosion set back, including SLR (m)
2440	0	0	40
2440	0.5	130	170
2440	1	260	300
2440	2	530	570
2444.5	0	0	40
2444.5	0.5	50	90
2444.5	1	110	150
2444.5	2	120	260
2450	0	0	40
2450	0.5	110	150
2450	1	220	260
2450	2	450	490
2451 to 2455	0	0	40
2451 to 2455	0.5	10	50
2451 to 2455	1	20	60
2451 to 2455	2	30	70

As can be seen from Table 3, the total SLR *erosion* set back[12] for Beira thus ranges from 40 m to 570 m, depending on the alongshore location (erodibility, slope and wave exposure) and SLR scenario. These set-back distances are only a conservative first-order estimate to consider for the long-term planning of new developments or of major redevelopment of the coastal strip. Better topographic input data are needed if more detailed or accurate results are required.

[12] The erosion set-back lines in Table 1 relate to only one component of the risk factors that potentially impact on development and is expressed as a horizontal distance from the high-water mark. Other components that influence the recommended total set-back line (expressed as an elevation, in other words along the +8 m contour) include the SLR and storm-wave run-up. Both the erosion set-back lines (horizontal distance) and the recommended total set-back line (with an elevation above MSL) are estimates and need to be firmed up through field surveys. The position of the total set-back line will furthermore be influenced by the (adaptation) interventions implemented.

Figure 15A: Maputo-Costa do Sol area: Estimated contour lines

As can be seen from Figure 15A, many areas along the Maputo coastal edge are low-lying and thus vulnerable to the effects of climate change. The most vulnerable area in the short term is the approximately 6 km stretch of coastal road along the beachfront up to Costa Do Sol. Without intervention, infrastructure and people located in the areas below the +5 m contour line are already very vulnerable to extreme events during MHWS (which occurs approximately every 14 days) and in the low climate change scenario of 0.5 m SLR by 2100, even without considering wave run-up.

Figure 15B: Maputo port area: Estimated contour lines

As can be seen from Figure 15B, many of the existing Maputo port and adjacent developed areas are located below the estimated +5 m MSL contour position. They are therefore already considered vulnerable to extreme events during MHWS (which occurs approximately every 14 days) and in the low climate change scenario of 0.5 m SLR by 2100, even without considering wave run-up.

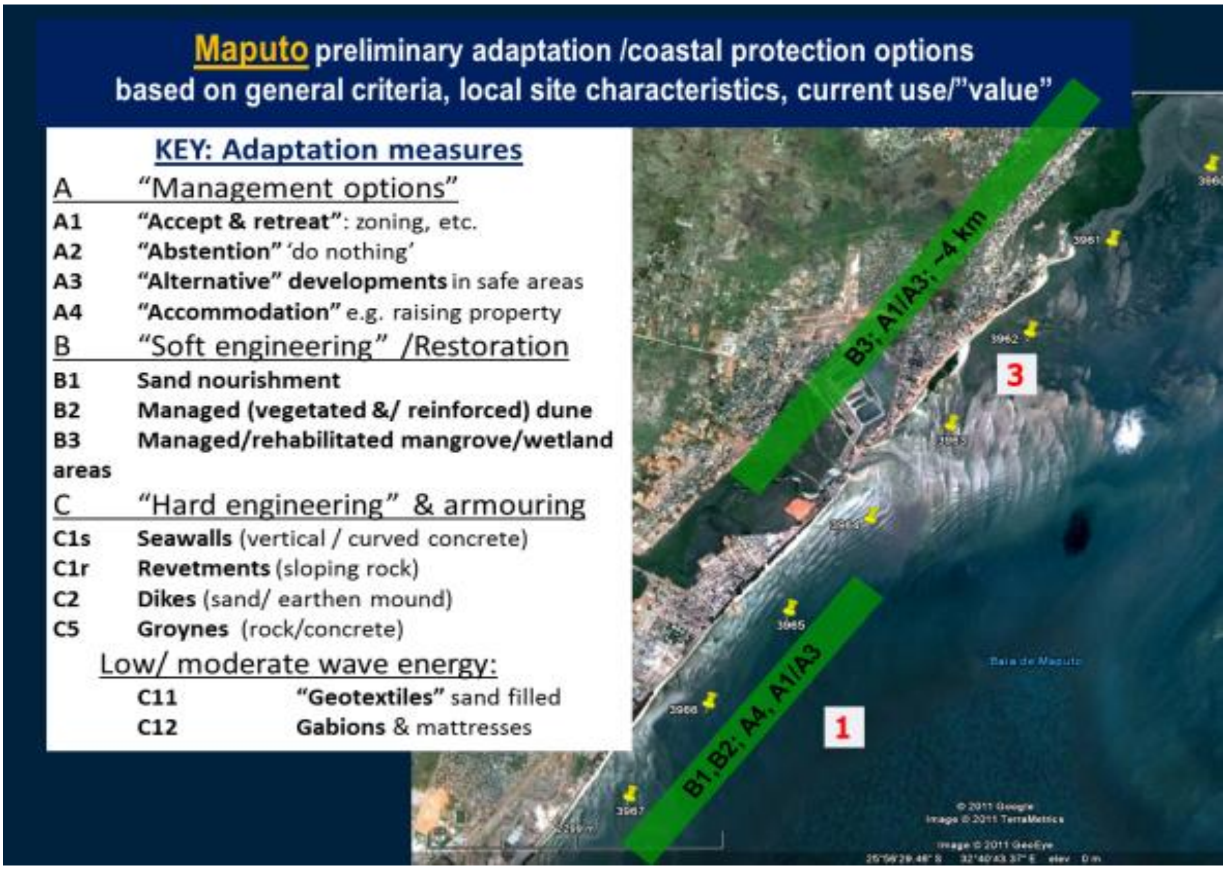


Figure 16: Eastern Maputo, including the Costa do Sol area: Intervention priorities no. 1 and no. 3 for Maputo

As can be seen from Figure 16, management decision options (A1, A3 and A4) are the most sustainable and ultimately less costly options here, along with several soft-engineering options.

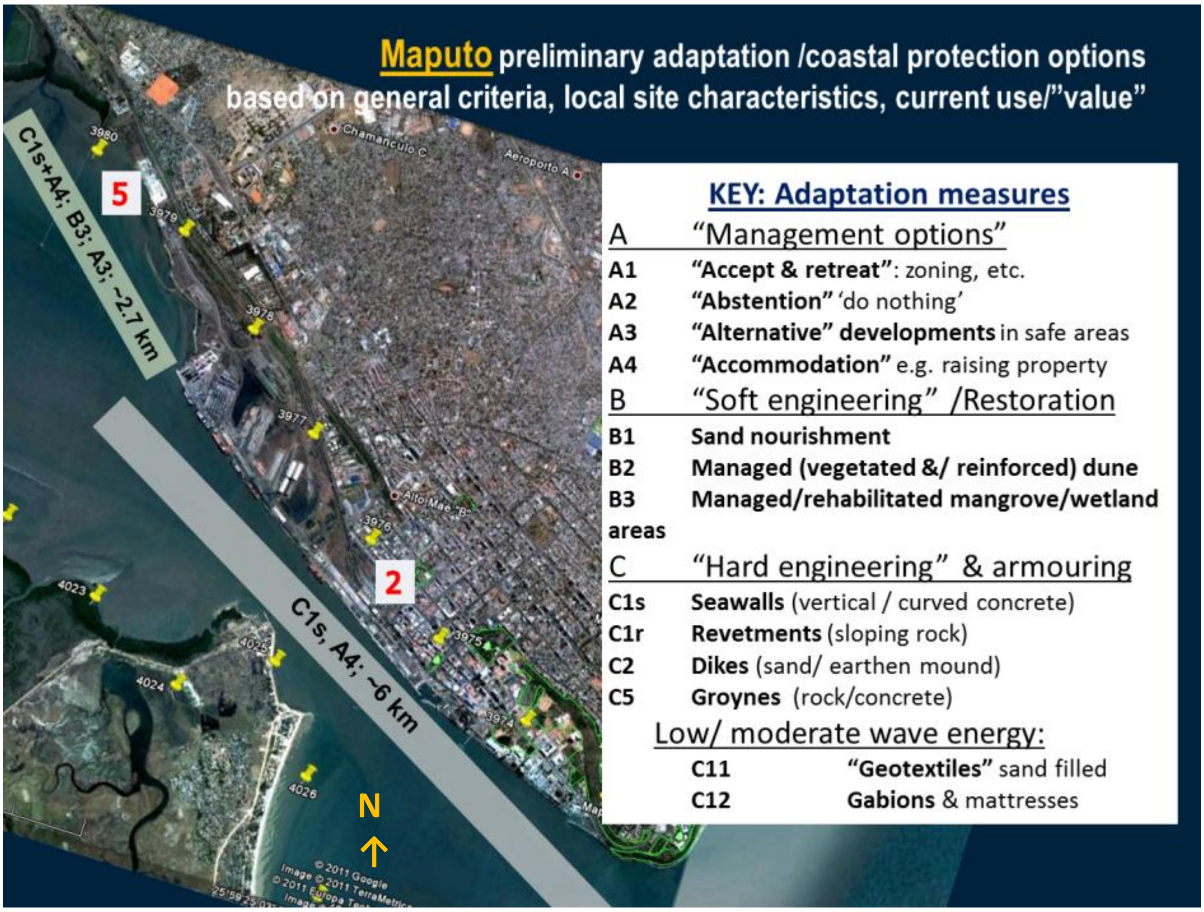


Figure 17: Western Maputo: Recommended adaptation and coastal protection options

As can be seen from Figure 17, existing infrastructure is already too low in places (in other words, under present conditions, excluding SLR) and therefore needs to be upgraded and maintained as a matter of urgency (priority no. 2 for Maputo). Quay walls, wharfs, storage areas, transport infrastructure etc. located near existing port infrastructure will have to be raised in stages. The protecting sea walls will have to be similarly raised, where possible, or new walls will have to be constructed. It is recommended that the design of future port expansion works or refurbishment of existing infrastructure should include the option of the future heightening of the structures in stages to at least the +6 m MSL and, ideally, to the +8.5 m MSL level by 2100.

The western portion of the port area (from point no. 3977 westwards, marked as priority no. 5) and the river shoreline further inland are not vulnerable to wave set-up or run-up. Potentially, the design flooding level along these areas could be as low as +4.5 m MSL for sea flooding events. However, the joint effects of an extreme river flood (not within the scope of this study) with high inshore sea-water levels (both resulting from a cyclone) could forseeably result in higher flooding levels. It is also more practical to have all port infrastructure at the same ground level, where possible. The +6 m MSL design level is therefore also recommended for these areas. These levels should be reviewed as accurate river flooding levels and more accurate SLR projections become available in the future.

A practical, quick-win solution to the erosion of this important section of the coastline is to collaborate with the Port of Maputo on sand dredging. The port entrance channel is dredged regularly to keep it deep enough and the sediments are dumped in deeper water away from the shoreline. The erosion problems could be alleviated, however, if suitable dredged sediments were, instead, returned to the shoreline. Details are contained in the INGC Phase II report on coastal protection.

Figure 18: Pemba port area: Estimated contour lines

As can be seen from Figure 18, the Pemba peninsula provides only partial protection from waves and sea-water flooding when a cyclone moves inland across Pemba and significant local water level set ups and local wave run-ups can therefore occur. Many of the informal settlements in the Porto Amelia area are located between the normal high-tide line and less than 5 m above MSL, which makes this area particularly vulnerable to flooding from the sea. At the north-western tip of the city, the highly vulnerable village of Paquite is already regularly threatened by sea inundation.

Although it might not appear so at first glance, the current infrastructure at the port is relatively vulnerable to expected climate change impacts in conjunction with a cyclone moving over the bay.

The eastern and northern shores of Pemba outside the bay are exposed to cyclone waves approaching from the north-east or north. Along these more exposed shores, the intermediate safety hazard level of +9 m MSL is appropriate for the planning and management of infrastructure with a design life of less than 50 years (for a +1 m SLR by 2100 and a 3 m storm run-up during cyclones). Inside Pemba Bay, areas below the +8 m contour will be in danger of being flooded with a 1 m SLR by 2100 plus a run-up of +1.5 m during cyclonic events. The flooding level of +8 m MSL is appropriate for infrastructure along the bay shoreline with a design life of less than 50 years.

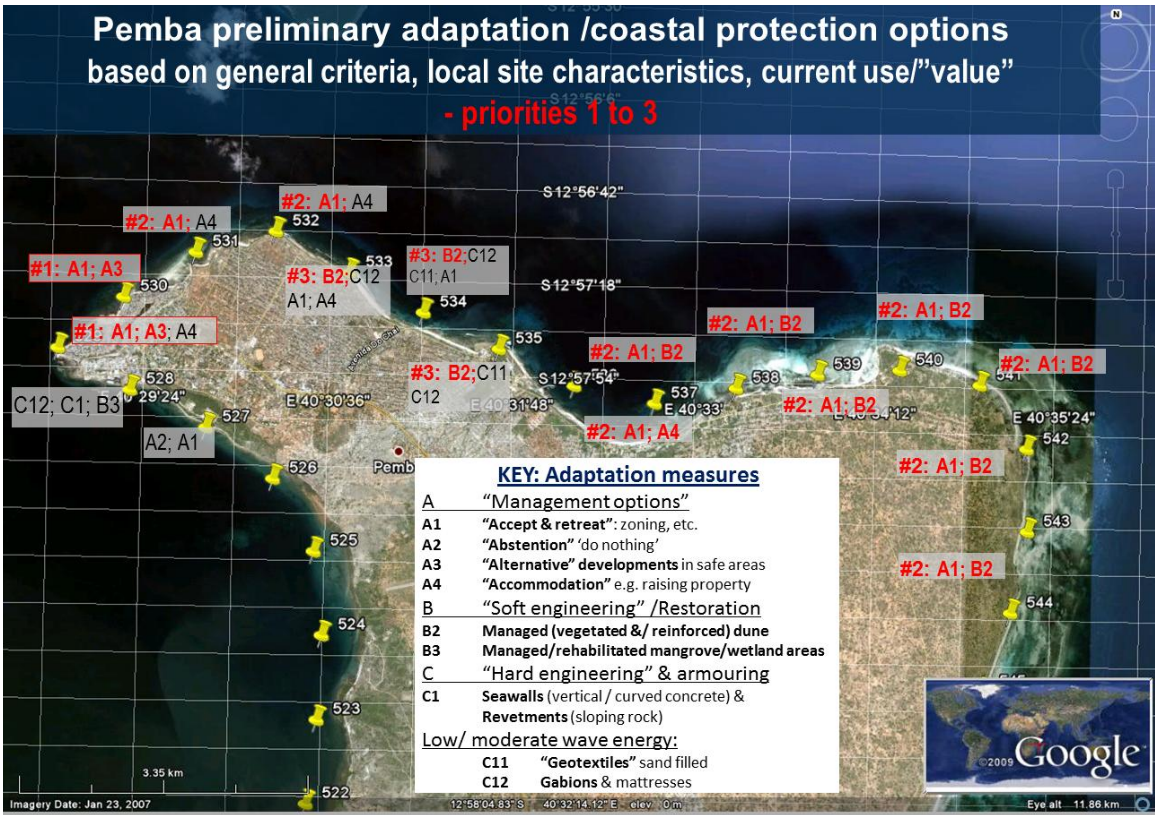


Figure 19: Pemba: Recommended adaptation and coastal protection options

As can be seen from Figure 19, zoning (A1) is recommended to prevent development from taking place in the hazard zone (priority no. 1). The no-development zone for the bay shoreline area (from no. 522 to no. 528) is typically above the + 8 m MSL contour level, while, outside Pemba Bay (from Porto Amelia to no. 544), the level of +9 m MSL and a minimum of 100 m from the high-water mark are appropriate in all instances.

Actively rehabilitating and managing the foredunes (adaptation option B2) are also a practical and inexpensive way of preventing damage to the coastline along the northern and eastern coasts of Pemba. The options of forming public-private partnerships could also be considered.

New developments should be designed to cater for the identified climate change factors and to assist the municipality with the implementation of the required adaptation works. Harbour development in the deep bay could also boost income to offset coastal protection costs.

Options C1s and A4 are the only practical suggestions for the port area. The design of future port expansion works or refurbishment of existing infrastructure should include the option of the future heightening of the structures in stages to the +9 m MSL level by 2100. This level should be reviewed at 10-year intervals as more accurate SLR projections become available in the future.

Municipal reactions

During 2011, the INGC engaged with the municipalities of the key study sites in the form of workshops and missions. The aim was to discuss the preliminary findings and their implications with the municipal officials and role-players responsible for the technical and/or management aspects of the coastal areas within the specific municipal areas. The most important outcomes of these discussions are summarised in Box 4.

Box 4: Main points from discussions with municipalities on coastal climate change risks, June to August 2011

The current municipal structure plans do incorporate general environmental issues but do not specifically consider climate change issues.

Common to all the interaction was a request to disseminate the results of the study to a broader stakeholder base.

At all the meetings, the technical municipal staff found the information to be relevant for current and future structure plans and were willing to use the results of the study.

Validation must be obtained from the state and the provinces before implementation can be achieved. Higher-level municipal authorities and other decision-makers therefore have to be engaged to facilitate the successful incorporation of the findings and the recommendations on current and future structure plans.

There is a critical shortage of skills and management capacity at both a technical and an administrative level. The need for active development and for the transfer of technology and skills was highlighted in all cases.

Various studies and overlapping initiatives are taking place within the study area. The municipal officials highlighted the need to coordinate and align these to avoid confusion and the duplication of efforts and to avoid conflicting recommendations.

Some of the actions required to adapt to climate change may be costly and may not be supportable by the municipalities. It was indicated that there is a high potential for public-private partnerships in all the coastal municipalities and that this type of cost-sharing mechanism should be considered in the assessment of or request for development proposals.

Costs of coastal adaptation priorities

The costs for Beira and Maputo, excluding the management options, are summarised in Annex 4. The minimum costs for the soft and hard-engineering measures combined (excluding the management options) for Beira are estimated at US$32 million and, for Maputo, at US$59 million. The maximum costs are 10 times these amounts. Final costing can be confirmed only once site-specific engineering designs and environmental investigations have been carried out.

Note that the recommended first priority for Beira is alternative development in a safe location for the present informal settlement in the wetland area, plus rezoning of this area. This is a management option for which no cost estimations were made. The reason for this is that an in-depth socio-economic study is needed to determine the costs of the many external and socio-economic factors involved in implementing such recommendations versus direct and indirect benefits (and future cost savings).

General recommendations

In addition to the site-specific adaptation options, the following measures are strongly recommended:

(i) The implementation of integrated coastal planning and management

Most of the response options follow an integrated coastal planning approach, which is in line with strategic principles and best-practice guidelines in terms of coastal management and response to climate change. Management decisions will go a long way to reducing the need for constructing expensive coastal defences in many instances, especially in the long term. The following are some examples of such decisions:

Plan any coastal construction so that it is a safe distance away from the high-water mark and reinstate natural defence mechanisms, with the necessary environmental authorisation.

Undertake a holistic approach through the development and implementation of coastal management programmes that incorporate shoreline management plans.

Establish a coastal development set-back line that is designed to protect both the natural environment from encroachment by buildings and beachfront developments from the effects of storms and accelerated coastal erosion.

Protect the integrity of buffer dune systems, which should be vegetated with appropriate dune species as per the original natural zones and be maintained.

Maintain or, even better, increase the volume of the sand reservoir stored in the dune system.

Protect, restore and maintain natural systems, such as mangroves and coral reefs.

(ii) The finding of opportunities for public-private partnerships

Many opportunities for entering into design-and-build-type public-private partnerships with the potential of co-funding the implementation of the more costly hard-engineering adaptation options exist.

(iii) The continuation of active engagement and communication with stakeholders to disseminate outputs and facilitate uptake

Leaders should be encouraged to implement the prioritised no-regret adaptation measures as soon as possible. In most cases, this means adhering to sound planning and design principles and incorporating the results of the studies into current and future plans, such as municipal structure plans and public and privately funded development plans. Approved coastal development plans should be revised to ensure that the relevant climate-change-related factors are taken into consideration and that private developers are aware of the potential risks of not taking a precautionary approach.

(iv) The dissemination of knowledge and the provision of decision support

To enable informed, evidence-based decision-making, a dissemination strategy should be carried out to ensure the effective dissemination of the results of this study at national, provincial and municipal levels. An information and education drive should be started to raise wider local population awareness. The centre of knowledge on climate change should provide research and advisory services and decision support tools, such as maps, GIS databases and reports, and practical rule-based guidelines for use by the coastal management communities should be developed. Formal climate change adaptation-related skills development programmes at all decision support levels (management, administration and technical levels) should be developed.

(v) The improvement of data collection and monitoring

In any follow-up phase of work, it is essential to include additional data collection and monitoring as a priority. These would address the critical gap in the regional, national and local-level data and information required to enable detailed planning and design and to increase the level of confidence in the key sets of information on which the adaptation measures identified in this study are based. Detailed topographic and bathymetric data at identified priority areas, the monitoring of shoreline stability and trends, and the integrity of built and natural coastal defences are critical to any proper integrated coastal zone management and sustainable coastal development assessments and plans. It is therefore strongly recommended that actions be taken to ensure the effective monitoring of all the above-mentioned parameters.

4.2 THEME III B: PREPARING CITIES

> *"Adapting to a warmer world is a necessity, but it must be planned carefully and must rest on a sound economic footing."* – Angel Gurría, Secretary-General, Organisation for Economic Co-operation and Development (OECD)[13]

Mozambican cities are already losing GDP through climate change impacts[14]. Projections on future climate trends show that these impacts will become more severe. Annex 5 summarises the vulnerability analysis of three important cities in Mozambique: Maputo; Beira; and Quelimane.

An economic analysis of the impact of climate change on the three city's GDPs shows that, for Beira, the current expected loss of approximately US$20 million could increase five-fold to between approximately US$95 million and US$185 million or 5% to 9% of GDP[15] by 2030. For Maputo, the current expected loss of approximately US$50 million could increase to between approximately US$160 million and US$275 million or 4% to 5% of GDP by 2030 (INGC Phase II, 2012). Quelimane's current expected climate-related loss of about US$8 million could increase to between US$40 million and US$45 million by 2030 or 4% to 5% of GDP.

This expected loss is an average that can mask the potentially devastating impact of lower-frequency events, the intensity and frequency of which are expected to increase with climate change, resulting in years with more significant losses.

Part of the expected loss for each city could be averted by implementing adaptation measures. The expected loss averted by 2030 for Beira would be in the order of between US$60 million and US$70 million and approximately US$80 million for Maputo should the short-listed measures with a cost-benefit ratio of less than 1.5 be implemented. The net loss averted with cost-effective adaptation measures for Quelimane would total approximately US$15 million by 2030.

The implementation of these adaptation and mitigation measures would allow Beira to reduce the economic impact of disasters by approximately 43% under the moderate climate change scenario. For Maputo, this would be approximately 37%, as it would be for Quelimane. This is a clear imperative to set and implement adaptation measures sooner rather than later.

Despite a strong economic rationale, adaptation measures represent very significant investment. Looking at the cities of Maputo, Beira and Quelimane as a whole (in other words, not at coastal protection only) and at cost-effective adaptation measures only (in other words, measures with a cost-benefit ratio of less than 1.5), capital expenditure investment of approximately US$400 million over the next five years would be needed for Maputo. Much of this would have to be spent on inland flood protection measures. Beira would require approximately US$270 million in cost-effective measures (mostly coastal interventions). Quelimane would require approximately US$40 million over five years, mainly for inland flooding measures.

[13] http://www.oecd.org/document/2/0,3746,en_2649_34361_40691458_1_1_1_1,00.html (2008, May).
[14] Benson, C. & Clay, E. 2001. *The impact of drought on sub-Saharan African economies.* Technical paper 401. World Bank; World Bank. 2005. *Memorandum – The role of water in the Mozambique economy identifying vulnerability and constraints to growth.*
[15] Corresponding to the moderate and high climate change scenario, respectively.

Some quick wins can and should be started immediately, such as mangrove rehabilitation and maintenance, which would also create green jobs locally (in other words, jobs for ecosystem care).

The adaptation measures that can produce the reduction in expected loss described above were selected through a screening process involving engineering, local authority, community and cost-benefit criteria. Combined, these measures address the main expected impacts of climate change – inland flooding, coastal flooding and epidemics – in Maputo, Beira and Quelimane.

Figures 20 and 21 show the recommended adaptation measures for the cities of Beira and Maputo, respectively. More results, including those for Quelimane, are contained in the INGC Phase II report *Protecting the City*.

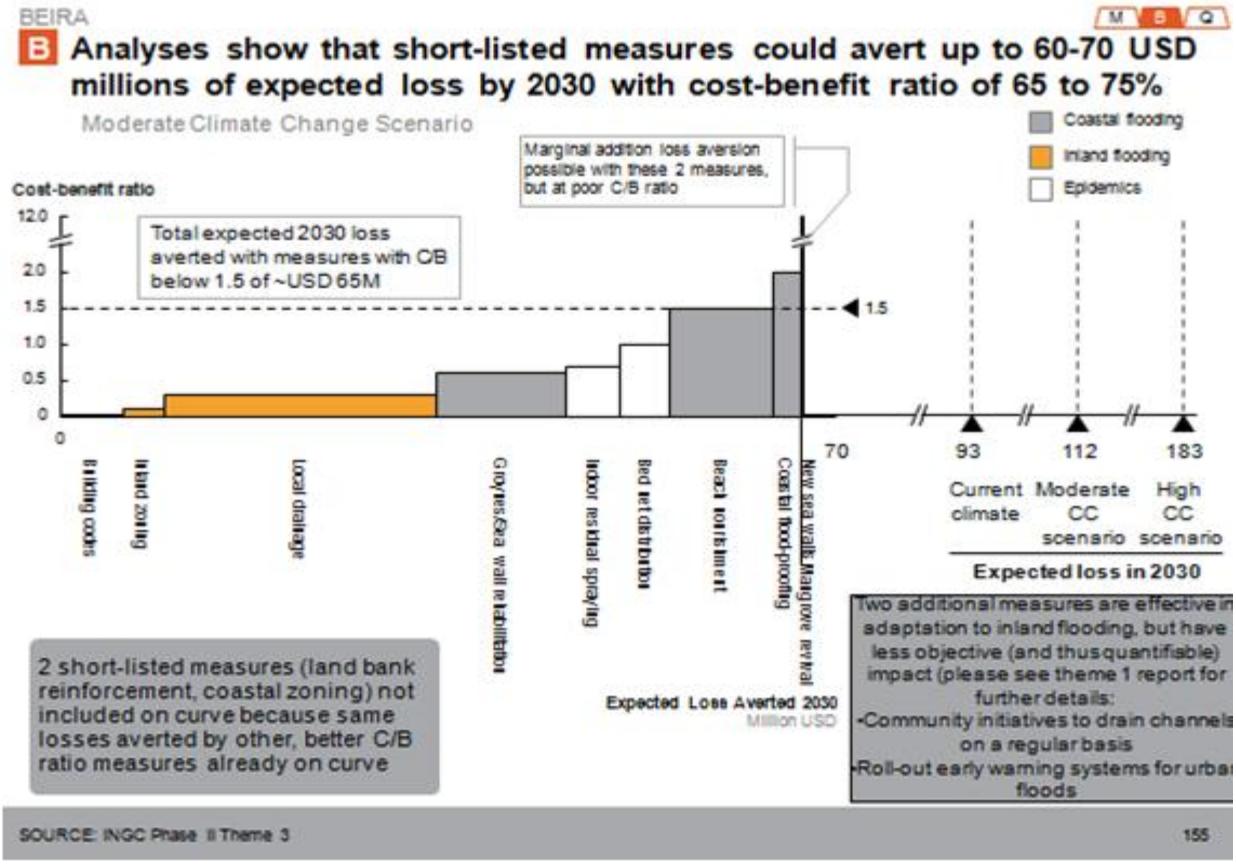


Figure 20: Entire city of Beira: Recommended adaptation options with a cost-benefit ratio < 1.5 (i.e. not just coastal flooding but also inland flooding and epidemics)

As can be seen from Figure 20, the width of each bar on the x-axis represents the losses that would be avoided if the specific measure were put in place. For Beira, local drainage would avoid the most losses of all the measures. Measures with a cost-benefit ratio of less than 1 would produce more benefit than they cost.

The bars are coloured according to the type of risk that each measure would help to avoid: orange for inland flooding; white for epidemics; and grey for coastal flooding.

The three lines all the way to the right are the total expected loss under the three climate scenarios of current climate, moderate climate change (a US$112 million expected loss by 2030) and high climate change. This curve notes the expected loss averted by 2030 as ranging between US$60 million and US$70 million, the sum of the costs avoided (the width of the bar) of all measures with a cost-benefit ratio of less than 1.5 and the proposed cut-off point for the implementation of a measure.

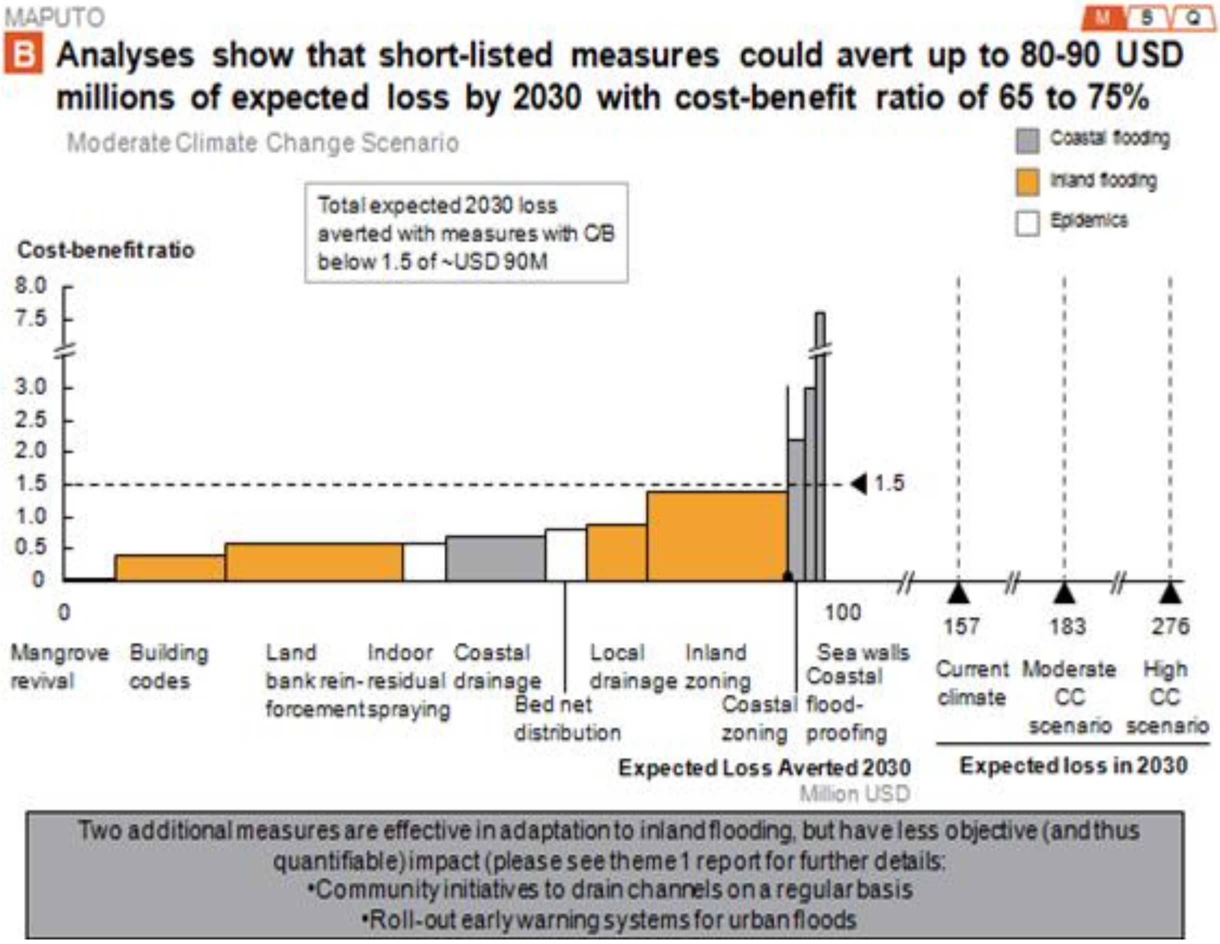


Figure 21: Maputo: Recommended adaptation options with a cost-benefit ratio < 1.5

As can be seen from Figure 21, the width of each bar on the x-axis represents the losses that would be avoided if the specific measure were put in place. Land bank reinforcement would avoid the most losses of all the measures, compared to cost. Measures with a cost-benefit ratio of less than 1 would produce more benefit than they cost.

The y-axis is the cost-benefit ratio for each measure and depicts the cost of the implementation of the measure relative to the benefits, in other words, cost avoided from climate change. The bars are sorted in order of increasing cost-to-benefit, meaning that those on the left produce the most benefit relative to their cost.

The bars are coloured according to the type of risk that each measure would help to avoid: orange for inland flooding; white for epidemics; and grey for coastal flooding.

The three lines all the way to the right are the total expected loss under the three climate scenarios of current climate, moderate climate change (a US$183 million expected loss by 2030) and high climate change. This curve notes the expected loss averted by 2030 as being US$80 million, the sum of the costs avoided (the width of the bar) of all measures with a cost-benefit ratio of less than 1.5 and the proposed cut-off point for the implementation of a measure.

Insurable losses are significant in all three cities of Maputo, Beira and Quelimane, which would greatly benefit from risk transfer mechanisms. For those events occurring with relatively high frequency, losses could be avoided cost effectively through adaptation measures.

At the far end of the spectrum are devastating events that occur only every several 100 years, for which Mozambique relies on international support. Under climate change, however, the intensity (and, possibly, the frequency) of these events could increase.

In the middle of the spectrum are low-probability, high-impact events for which the cities could transfer risk using financial mechanisms, such as an insurance policy. There are various types of insurance from which to choose. For the type of hazards faced by the three cities, parametric insurance is recommended or a combination of parametric insurance and contingent financing. These concepts are explained in Figure 22.

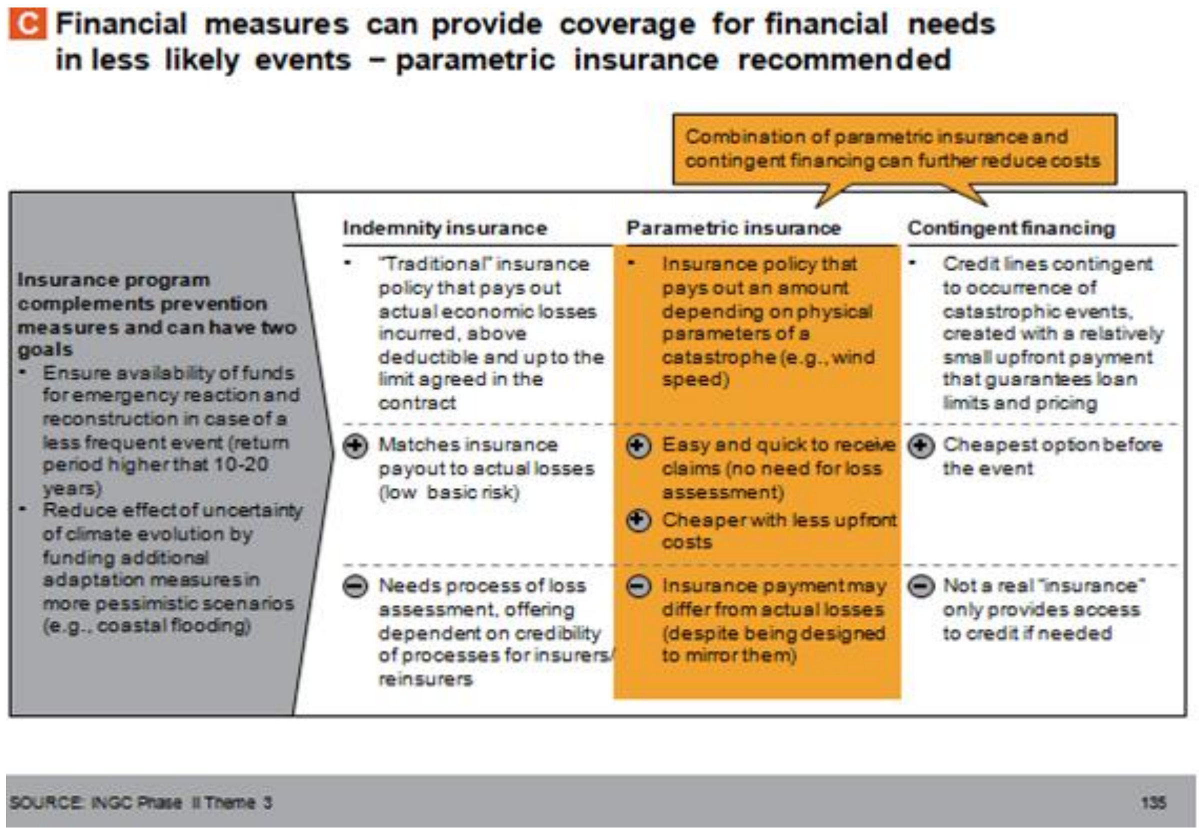


Figure 22: Risk transfer mechanisms for coastal cities

As can be seen from Figure 22, municipalities can select their degree of insurance protection by choosing their deductible (in other words, deciding how much risk to maintain themselves) and the frequency of events that they want to insure. For example, a bullet-proof policy level would cover a municipality against severe events projected to occur every 50 to 150 years. An average policy level would cover events projected to occur every 100 to 150 years.

Figure 23 lists the parametric index for Maputo for each level of insurance and each type of hazard, which, when attained during an event, would trigger an automatic payout of the insurance coverage. For example, in the case of the bullet-proof policy for coastal flooding, insurance would pay out automatically when the sea level at Maputo Port reaches 280 cm above MSL. In Beira, pay out in the case of a bullet-proof policy would occur at a level of 450 cm above MSL. In the case of Quelimane, with an average policy for inland flooding, insurance would pay out automatically when peak week precipitation reaches 450 mm; with a bullet-proof policy for inland flooding, insurance would pay out automatically when peak week precipitation reaches 400 mm (details are contained in the main INGC Phase II report).

Expected losses listed are greater for the bullet-proof policies because, while the triggering events are, on average, less severe for the 50 to 150-year events, they also are projected to occur more often.

MAPUTO

M B Q

C Insurance should cover most extreme events for the 3 hazards

Moderate climate change scenario

Hazard	Description	Potential parametric index		Insurance coverage scenario: "Bulletproof" ❶ 50-150-year events	Insurance coverage scenario: "Average" ❷ 100-150 year events
Coastal flooding	• Lower frequency coastal flooding levels that overwhelm coastal defenses	• Maximum sea level reached at port (cm above MSL¹)	Parametric Index	280 cm	300 cm
			Expected loss	USD 0.5 MM	USD 0.4 MM
Inland flooding	• Lower frequency inland flooding events not protected effectively by adaptation measures	• Peak week precipitation (mm)	Parametric Index	500 mm	560 mm
			Expected loss	USD 8.6 MM	USD 6.0 MM
Wind damage	• Tropical cyclones with wind speeds above 150 km/hr that cause substantial damage	• Maximum wind speed (km/hr)	Parametric Index	90 km/h	120 km/h
			Expected loss	USD 0.2 MM	USD 0.1 MM

1 Mean sea level

SOURCE: INGC Phase II Theme 3 137

Figure 23: Parametric indices per type of hazard and per city, which, when reached, trigger an automatic payout to the municipality of the insurance coverage

As can be seen from Figure 23, the cost of insurance for each city depends on the chosen range of events to be covered and on the city's deductible.

Figure 24 shows the calculation of the cost of insurance.

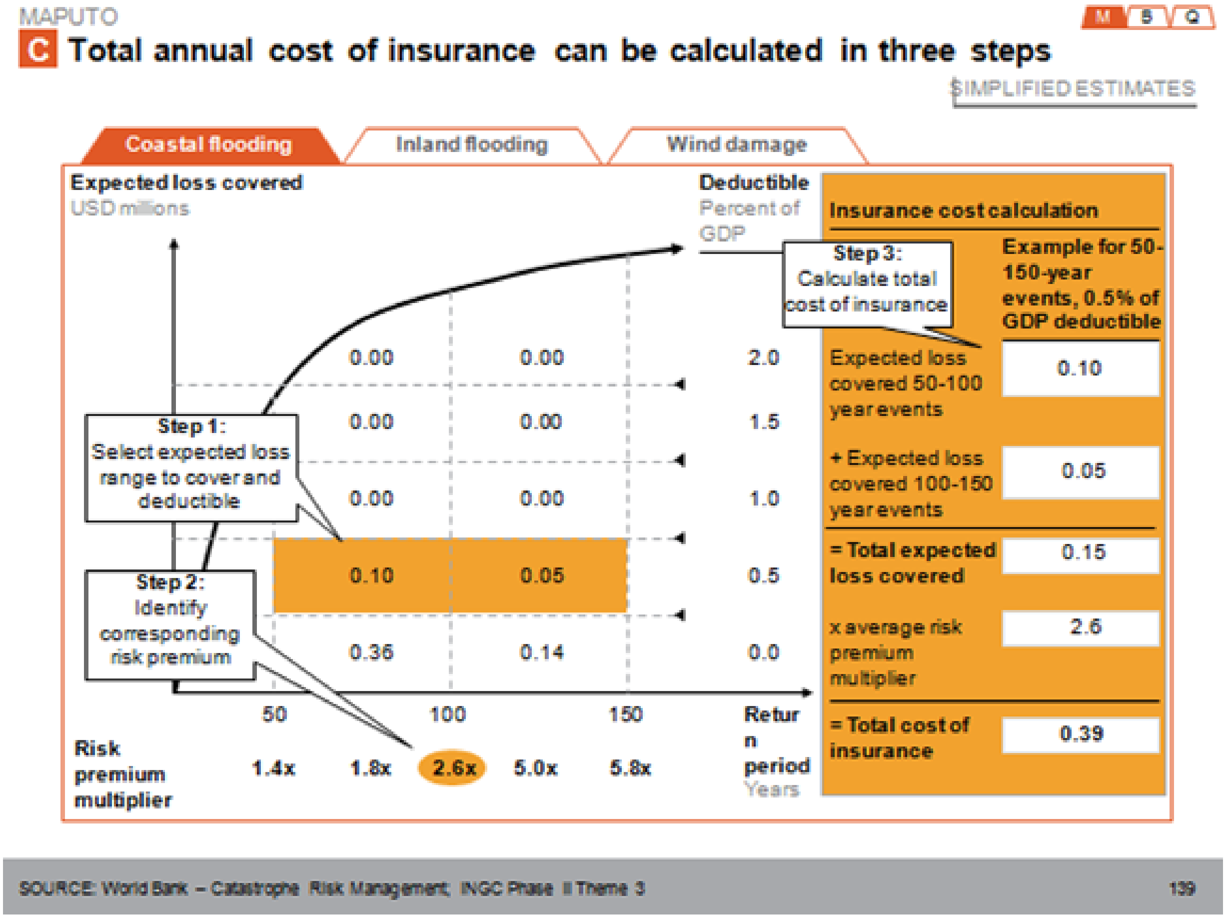


Figure 24: Maputo: Calculation of the cost of insurance

As can be seen from Figure 24, the first step shown is to select a range of events to cover and a deductible under which the municipality will cover itself (in this example, bullet-proof 50 to 100-year events and a 0.5% GDP deductible). The second step is to identify the risk premium multiplier that corresponds with that coverage range (in this example, 2.6). The third step is to calculate the total cost of insurance by multiplying the total expected loss covered by the risk premium multiplier (in this example, US$390 000 per year).

In the case of Beira, the annual cost of insurance for the same chosen scenario (bullet-proof 50 to 150-year events, a 0.5% deductible and a 2.6 risk premium multiplier) would be in the order of US$1.86 million because the expected loss is much greater.

These curves were calculated for each type of hazard. Municipalities can use these curves to determine their preferred range of coverage and deductible and to calculate the total cost of insurance. This will prepare the municipality for negotiations with insurers on the purchase of a policy for extreme event coverage. This exercise will be offered as part of the municipality training course at the centre of knowledge on climate change.

Economic analysis suggests that Mozambique, even with the losses from climate change becoming more severe, should set its ambition level to curb losses from climate change to 50% of the current level. To meet this ambition level, Mozambican cities would have to begin a five-year investment plan in adaptation measures, with specific investments tied to projected adaptation benefits through avoided losses. A look at best practices elsewhere (a three-country study) generated findings of interest to Mozambique (Annex 6).

Figure 25 outlines the main elements of the five-year plan proposed for Maputo, mapping out the major priorities for each year to set the municipality on the path to halving the current per cent of GDP impacts of climate change by 2030. Each part of the plan includes a combination of strategy development and planning, tactical planning and resource mobilisation, timing and geographic focus for high-priority adaptation measures, emphasis on pushing already planned or funded measures and the increased enforcement of the management oversight of new measures. Similar plans were made for Beira and Quelimane.

The implementation of the plan should be based on a broad set of partners and stakeholders at local, municipal, provincial and central level. Training in the adaptation strategy and techniques should be provided to stakeholders through the new centre of knowledge on climate change, once set up.

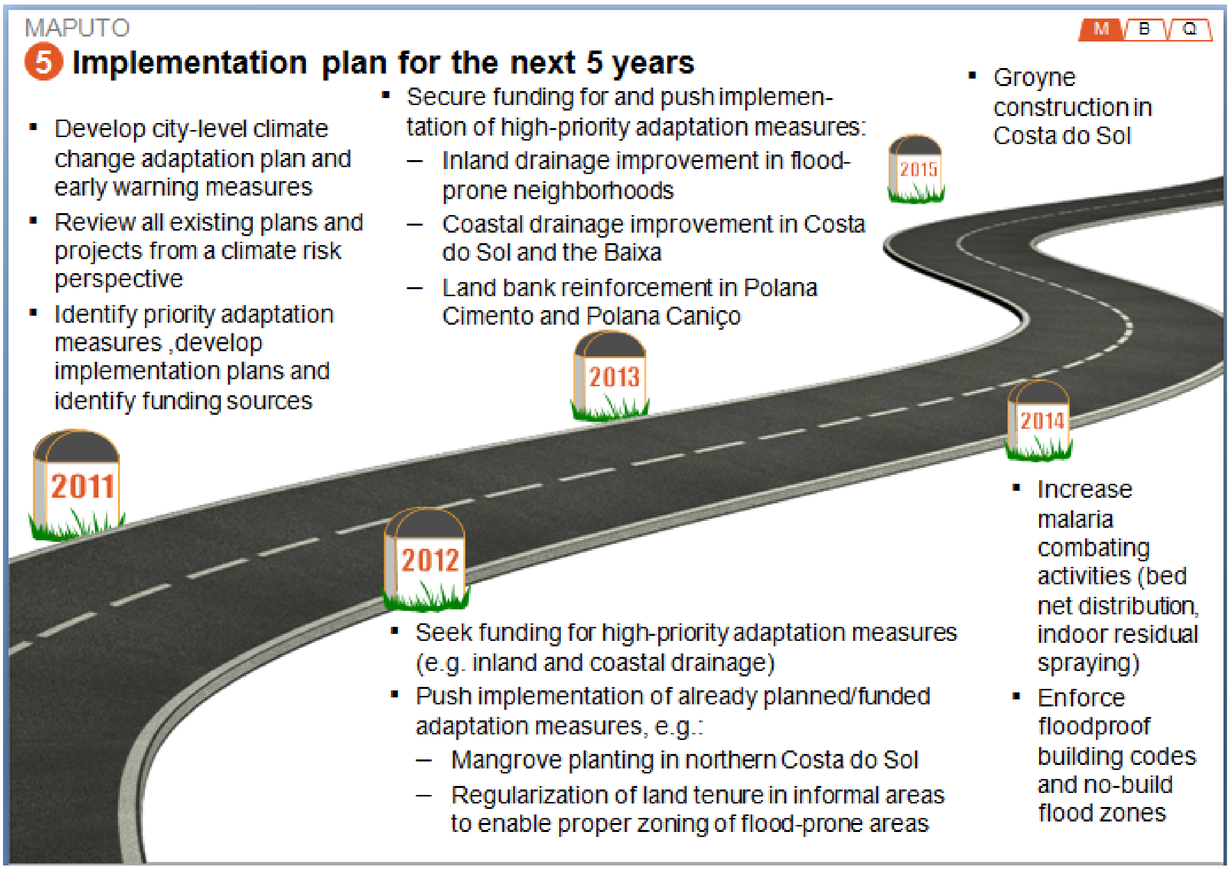


Figure 25: Maputo: Implementation plan for the next five years

As can be seen from Figure 25 and assuming the municipality continues with the ambition level of decreasing the costs of climate change, this five-year plan maps out the major priorities for each year to set the municipality on the path to halving the current per cent of GDP impacts of climate change by 2030. Similar plans were made for Beira and Quelimane (contained in the main INGC Phase II report).

Immediate next steps for the cities are as follows:

- To include the proposed climate change adaptation measures in legally binding documents for each city (such as *Plano de estrutura*).
- To begin with the implementation of the highly attractive no-regret measures (those with low cost-benefit ratios and low required capital expenditure) and with the highest coastal protection priorities (see the INGC Phase II report on coastal protection).
- To prepare a five-year adaptation investment plan that identifies a timeline for measure implementation, responsible actors and sources of funding.
- To form an adaptation planning and management unit within each municipality to lead the implementation of measures, with the mayor as the political champion of adaptation.
- To establish a systematic process for updating the prioritisation of adaptation measures and for monitoring the progress of implementation.
- In respect of Maputo, to undertake a joint review of the US$1 billion planned coastal investment project to ensure that climate change impacts and disaster risks are taken into account, to implement a mangrove planting project in northern Costa do Sol (collaborating with the port for sand nourishment using the existing dredging operations) and to secure funding for inland and coastal drainage and for land bank reinforcement projects (see the recommendations in the INGC Phase II report on coastal protection).
- In respect of Beira, to accelerate the implementation of World Bank and Arab Bank for Economic Development in Africa inland drainage and coastal protection projects and to secure funding for beach nourishment (see the recommendations in the INGC Phase II report on coastal protection).
- In respect of Quelimane, to incorporate an adaptation strategy in the city master plan and to accelerate the implementation of the millennium challenge account drainage project.

4.3 THEME III C: WATER: DOING MORE WITH LESS

““In rivers, the water that you touch is the last of what has passed and the first of that which comes; so with present time.” – Leonardo da Vinci

Water is increasingly in demand by multiple sectors and by neighbouring countries. Supply is therefore under pressure and showing higher variability. To understand the impact of climate change on water availability and flooding in Mozambique and to identify priority adaptation measures to deal with the increasing risks, the following four outcomes were achieved (including user training):

(i) The development and set up of a web-based interactive decision support system for the entire Zambezi basin to determine the impact of climate change and of upstream development and management (irrigation, hydraulic structures and land use change) on water availability in the basin.

(ii) The development of a flood model and flood maps for the Zambezi, Limpopo and Pungue in Mozambique showing flood risk areas under current and climate change conditions for two and 20-year return periods.

(iii) The in-depth analysis of urban flooding for a hot-spot area of Maputo, modelling current and projected flooding conditions and proposing specific solutions for flood alleviation (the methodology is replicable for other urban flooding hot spots).

(iv) The design of water retention and of alternative water use projects at farm level to increase agricultural water availability.

The following sections briefly describe the main results per outcome.

Decision support system

A water decision support system was developed for the entire Zambezi basin covering 1.4 million km² (almost double the size of Mozambique). The decision support system is a state-of-the-art, well-calibrated, easy-to-use analysis tool that can do a spatial assessment of the impacts of climate-induced changes, new water resource developments (such as dams or reservoir construction and operating rules or upstream irrigation projects) and land use change effects on downstream water supplies. It can also simulate the impact on water availability in Mozambique resulting from changing run-off (including variability) in the catchment areas outside Mozambique. Climatic data included in the decision support system cover the period from 1950 to 2005 for historical observations and from 1960 to 2100 for data of three climate models, thereby enabling simulations for any time slice between 1950 and 2100. What-if questions, such as "What if the temperature increases by 3° C and precipitation decreases by 10%?", can be easily analysed.

Components of the decision support system include an information management system and a river basin model. The information management system includes a web-based graphical user interface, a dynamic database, GIS components and analytical tools. The map display in the user interface integrates GIS layers, model elements and dynamic background maps (using the OpenStreetMap and Google maps). The river basin model consists of a water balance module and a water allocation module. Both these modules use monthly time steps.

The decision support system will serve as an important scenario analysis tool for water resource management in the Zambezi basin and can be expanded to include other river basins, such as the Limpopo and Pungwe.

The training of a selected team of early-warning analysts across ministries will start in 2012 and will be repeated throughout 2013. An on-line user manual will allow other users to apply the web-based decision support system.

Examples of decision support system analyses are given below. Outcomes show a high sensitivity and high complexity of regional changes in the Zambezi basin under various scenarios.

Figures 26 to 30 show temperature and precipitation changes in the Zambezi basin under the Intergovernmental Panel on Climate Change (IPCC) A2 emission scenario (essentially the too-little-too-late scenario in terms of the curbing of emissions globally). Under this scenario, air temperature in the Zambezi basin is projected to increase significantly until the end of the 21st century. Disaggregation by sub-basin shows that there are regional differences in projected warming of up to 1.5° C. For precipitation, no significant change is projected if *aggregated* for the entire Zambezi basin. By contrast, however, an analysis by *individual sub-basin* reveals that, in the upper regions of the basin, precipitation is projected to decrease significantly (by up to 30%), whereas, in the Shire River basin (sb_25 and sb_26), projections show an increase. This emphasises the need for the spatially distributed assessment of climate change and for the careful consideration of the uncertainties involved in climate change predictions.

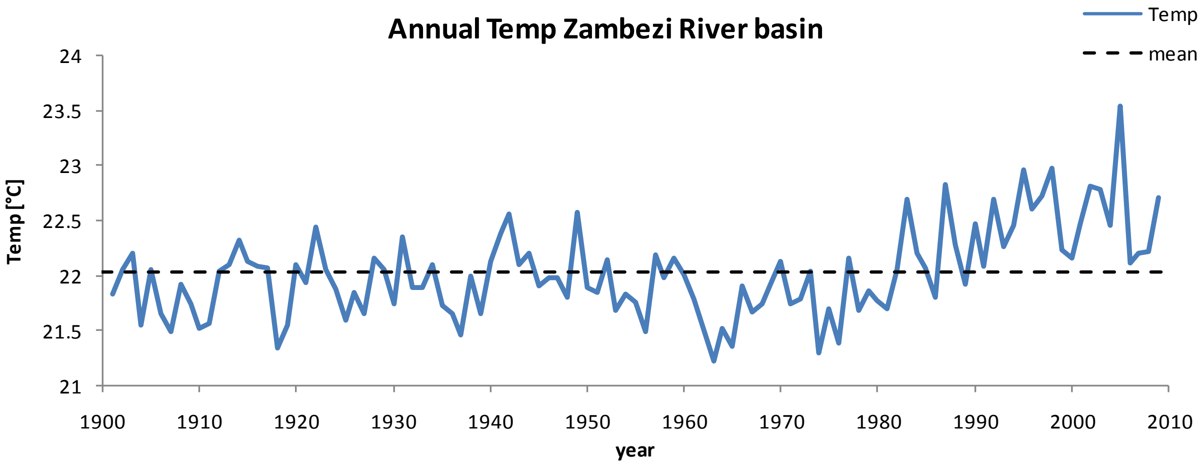


Figure 26: Zambezi basin: Annual temperature from 1901 to 2009 (Climatic Research Unit [CRU] data)

As can be seen from Figure 26, it was found that a warming by 1° C results in an increase in potential evapo-transpiration by 2.5%. This relationship was obtained at all the stations in the Zambezi basin, with only small variations. Tests showed that this rate in increase in potential evapo-transpiration is also scalable for higher degrees of warming.

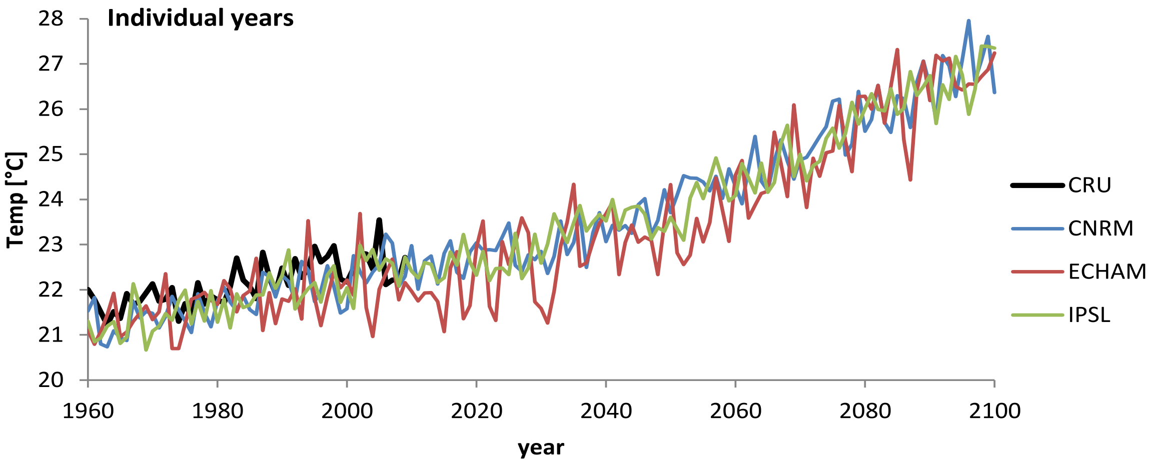


Figure 27: Zambezi basin: Annual air temperature simulated by four GC-MSs for the SRES A2 emission scenario (the too-little-too-late scenario in terms of the curbing of emissions globally) and observed CRU data aggregated over the full Zambezi basin

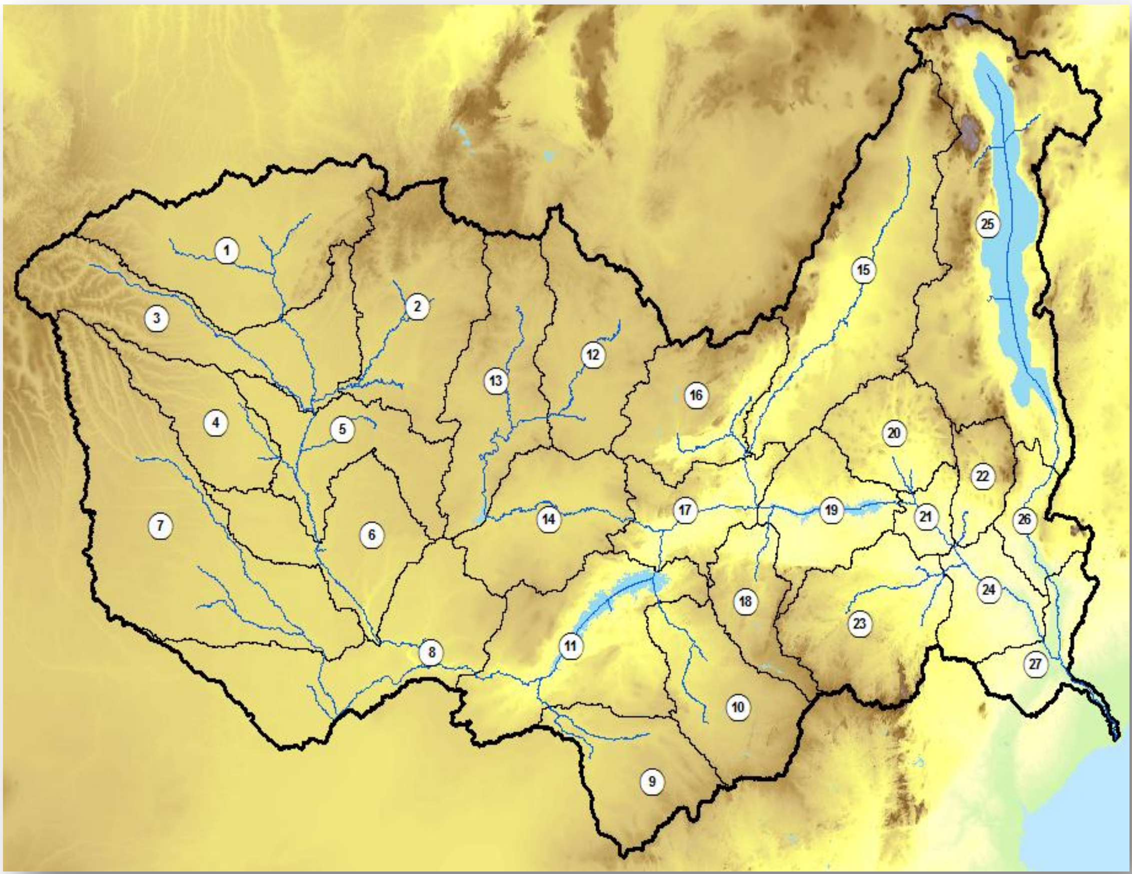


Figure 28: Zambezi sub-basins of the water balance module

Figures 29 and 30 refer to these sub-basins.

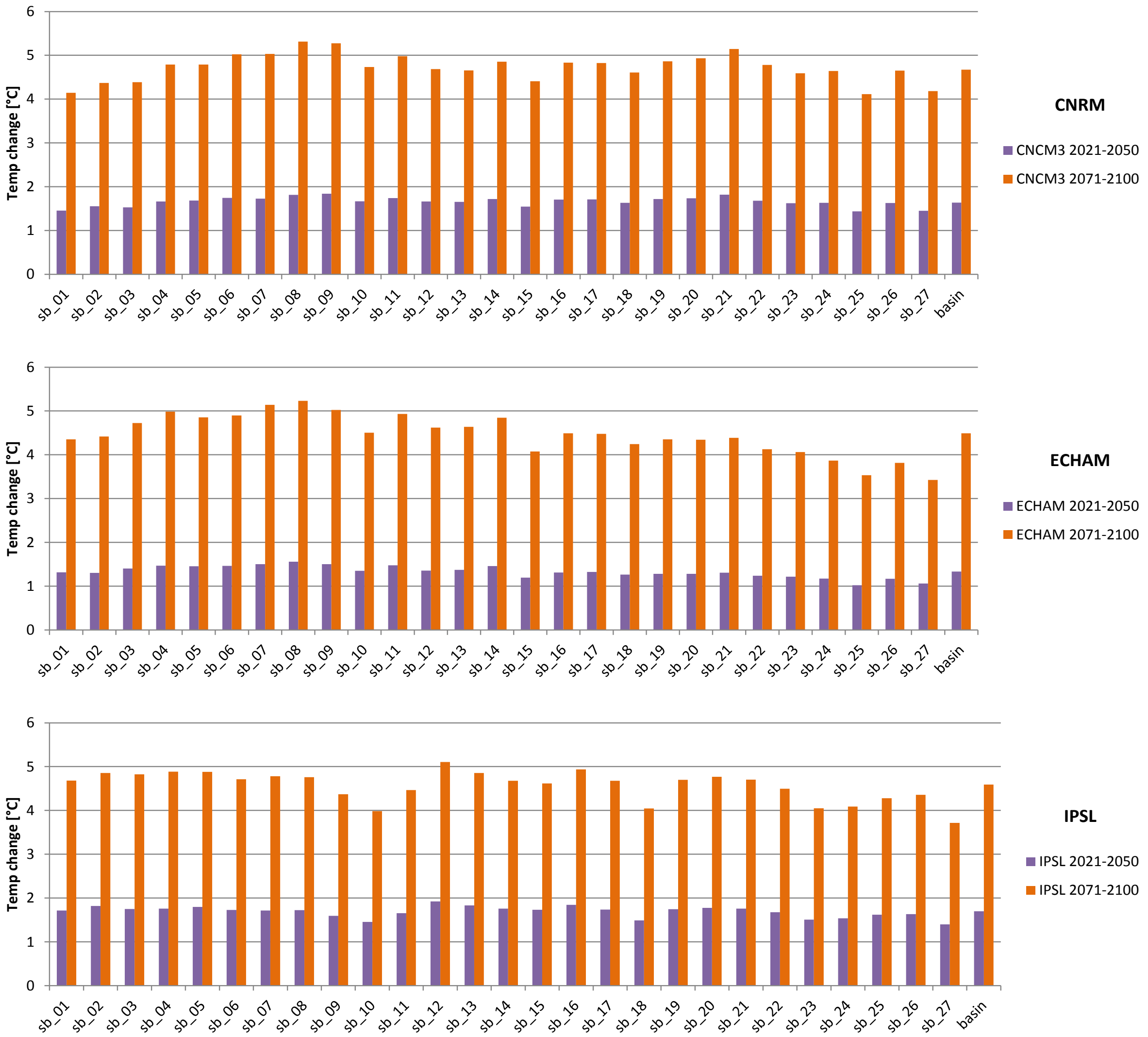


Figure 29: Each of the 27 different Zambezi sub-basins: Change in annual temperature projected by three climate change models using the SRES A2 scenario (the too-little-too-late scenario) (For a definition of "sub-basin [sb]", see Figure 28.)

As can be seen from Figure 29, all three GC-MSs project an increase in temperature across the entire basin of between 1° C and 2° C for the period up to 2050 and between 4° C to 5° C for the period 2070 to 2100.

Figure 30: Change in the annual precipitation of different sub-basins projected by the three climate models of the A2 emission scenario (the too-little-too-late scenario). Top: CNRM model data; middle: ECHAM model; bottom: IPSL model. (For the locations of the sub-basins, see Figure 24.)

As can be seen from Figure 30, an analysis by individual sub-basin reveals that, in the upper regions of the basin upstream of Victoria Falls (sb_01 to sb_11), precipitation is projected to decrease significantly (by up to 30%), although this will have only a minor impact on river discharge in these areas. Downstream of Victoria Falls, the IPSL projects an increase in precipitation, which will lead to high increases in river discharge, notably in the Shire River basin (sb_25 and sb_26). The Shire is already prone to flooding. This emphasises the need for a spatially distributed assessment of climate change.

Example study: Hydropower

Several hydropower projects are planned in the Zambezi River basin, including the refurbishment and extension of existing power plants and the construction of new facilities. For the predefined hydropower development scenario in the decision support system, two projects with a particularly high impact on the hydrology of the river were considered: Batoka Gorge upstream of Kariba and Mphanda Nkuwa downstream of Cahora Bassa (Figure 31). Both facilities are expected to be completed by 2024.

Figures 31 to 33 illustrate an example analysis of climate change and the implications of development on water availability for hydropower.

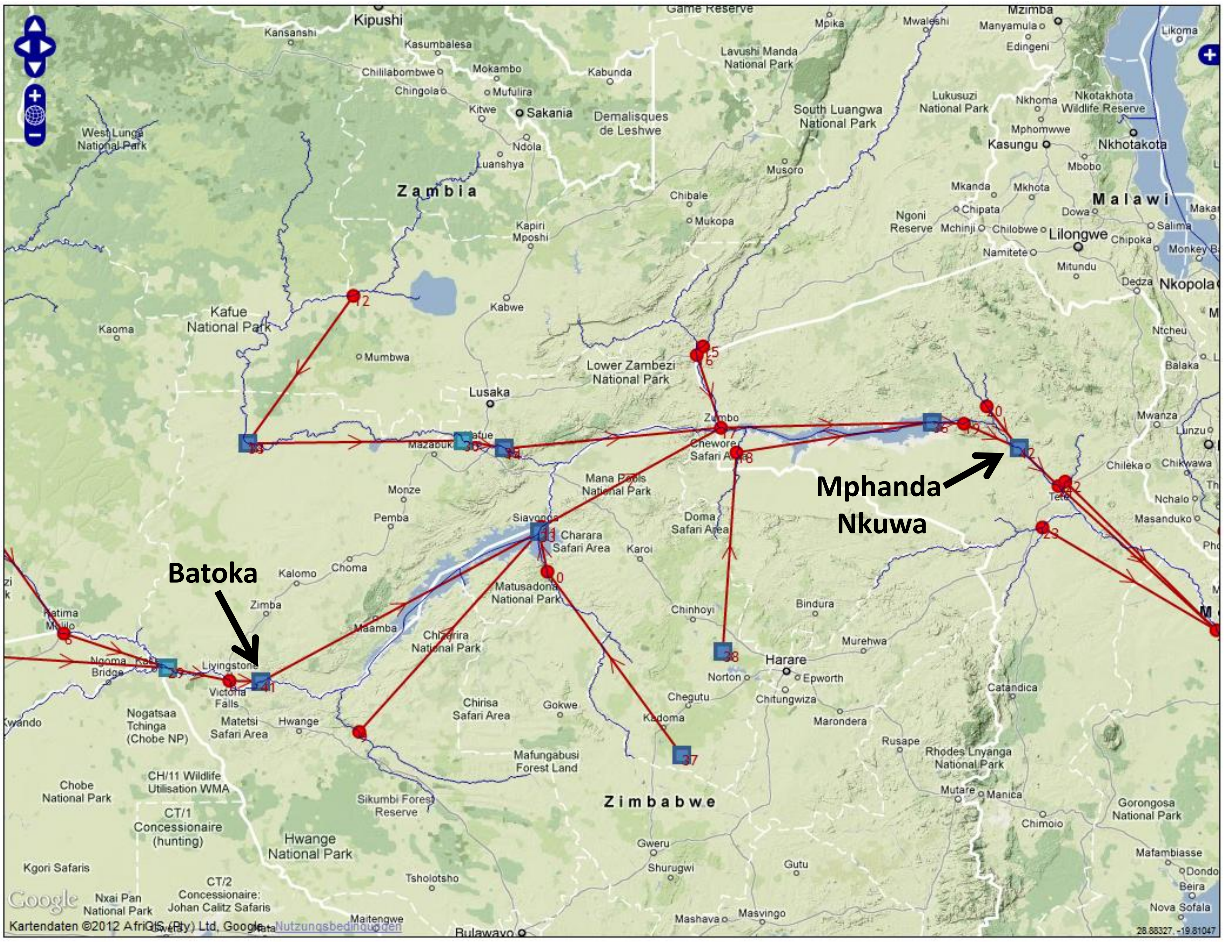


Figure 31: Computation point network for the hydropower case study, including the planned reservoirs of Batoka Gorge and Mphanda Nkuwa

As can be seen from Figure 31, in the predefined hydropower scenario, the commissioning date (the year in which the operation starts) of the reservoir is set for 2020 to overlap entirely with irrigation scenario 1.

For the power plant at Batoka Gorge, an installed capacity of 1 600 MW is planned. The 181 m high dam will generate a reservoir with a storage capacity of 1 600 hm³ and a surface area of 25.6 km² at full supply level. For Mphanda Nkuwa, an installed capacity of up to 2 700 MW is considered. At full supply level, the reservoir is planned to have a storage capacity of 2 324 hm³ and a surface area of 96.5 km². These planned reservoirs are small when compared with the existing Kariba and Cahora Bassa reservoirs.

In the example assessment, two development scenarios (the high irrigation development scenario with high water extraction and the moderate irrigation development[16]) are combined with the DELTA change climate scenarios described earlier. The moderate irrigation development scenario is analysed for the period 2021 to 2050 and the high irrigation development scenario is analysed for the period 2071 to 2100.

The results for the climate change scenarios without irrigation and hydropower development are shown with the dashed line in Figure 32. The impact of the development on river discharge is clearly visible in both periods, with the highest impact in the high-development scenario during low-flow months. The part of Figure 32 on the right shows that there is almost no river flow at Tete during a considerable part of the analysed period of 2071 to 2100. This is due to Cahora Bassa reservoir water levels falling below the minimum operational level for several months and no water being able to be released downstream. This shows that the planned operational rules (included in the decision support system) should be adapted under this scenario of climate change and high development.

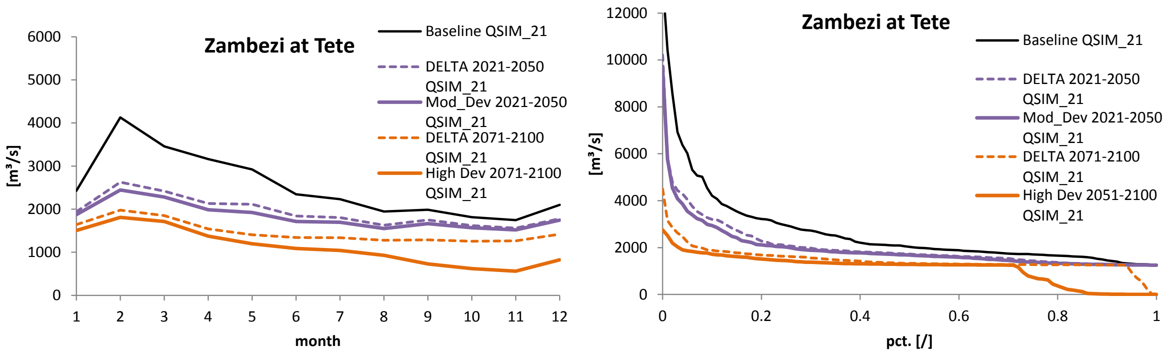


Figure 32: Tete: Long-term mean monthly discharge (left) and the flow duration curve (right) under the climate change and high development (brown line) and moderate development (blue line) scenario

As can be seen from Figure 32, the dotted lines show the results for the climate change scenarios without irrigation and hydropower development. The graph on the left indicates that, in the long term (from 2071 to 2100) and under mean monthly conditions, the flow will reduce considerably under the high development scenario. The graph on the right shows that, under the high development scenario (from 2051 to 2100), there may be significant periods when the river may run dry.

[16] Extraction rates are based on the 2010 World Bank study *The Zambezi River basin – A multi-sector investment opportunity analysis* Vol. 3, State of the Basin, p. 202.

Figure 33 shows the mean annual discharge of the entire Zambezi River basin under selected climate change and development scenarios.

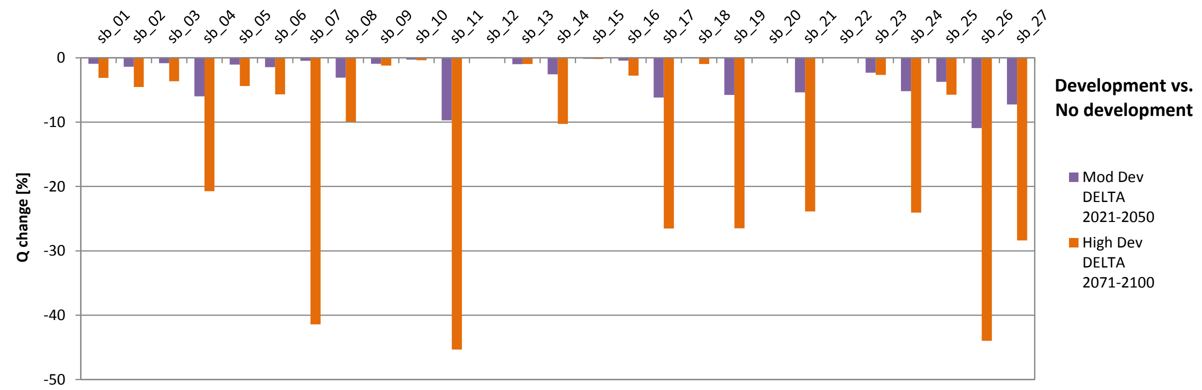


Figure 33: 27 sub-basins: Change in annual discharge for the high development scenario (the brown bars) and the moderate development scenario (the blue bars) compared to the DELTA change climate scenario without development

As can be seen from Figure 33, river discharge will decrease considerably in many sub-basins, especially under the high development (brown bar) scenario.

Figure 34 shows the strong impact of the high development scenarios on discharge per sub-basin.

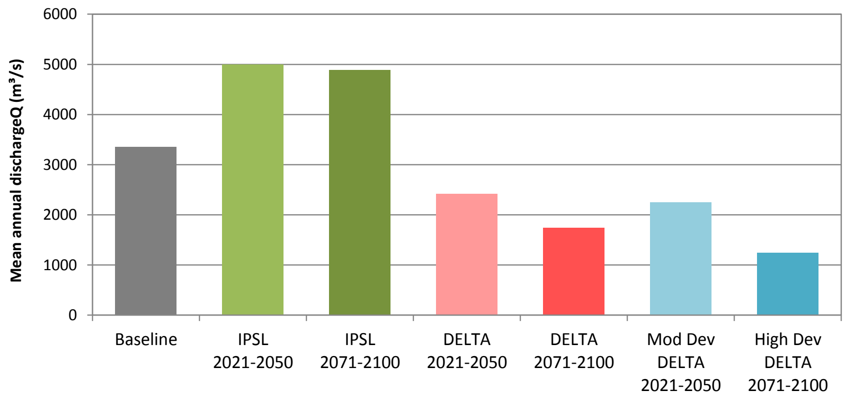


Figure 34: Entire Zambezi River basin: Mean annual discharge under selected climate change and development scenarios

As can be seen from Figure 34, the grey bar on the left represents the baseline scenario, which refers to the climate input from 1961 to 1990 and the current development (hydropower and irrigation withdrawals). The blue bar on the right represents high development under climate change. The graph shows that, under the DELTA scenario, the flow decreases considerably and even more so with concurrent high development17, while, under IPSL conditions, an increase in flow may be expected18.

[17] The DELTA approach applies uniform changes in temperature and precipitation across the entire Zambezi basin. Values are based on a reduction of 5% in precipitation for 2021 to 2050 and 10% in precipitation for 2071 to 2100. This scenario results in considerable decrease in river discharge (distributed fairly uniformly over the year), especially when combined with high development. The most pronounced changes (increases) occur in the Shire River.

[18] The IPSL model applies an increase in precipitation of between 5% and 10%, which leads to a drastic increase in river discharge, especially in the earlier period from 2021 to 2050 (in the later period from 2071 to 2100, the higher evapo-transpiration attenuates the increase in discharge) and more so during the wet season from January to April. The most pronounced changes (increases) occur in the Shire River.

The impact of development-only is recognisable by comparing "Mod Dev DELTA" with "DELTA 2021–2050" and "High Dev DELTA" with "DELTA 2071–2100". The combined impact of climate change and development is recognisable by comparing "Mod Dev DELTA" and "High Dev DELTA" with "Baseline".

Box 5: Understanding uncertainty and risk

The issue of uncertainty is crucial to understanding past and future climatic change, especially in the design of adaptation strategies that will benefit both present and future socio-economic situations. Uncertainty does not mean that we have no confidence in our projections of future climate. Indeed, all climate projections, including seasonal forecasts, are couched in terms of the probability of certain climate conditions occurring in the future. This is the framework within which humans often operate, allowing an assessment of future risks, such as the consideration of financial and investment opportunities.

To be able to assess risk, one needs to consider all sources of information. It is therefore essential that a probabilistic framework is used to develop projections, which should incorporate different sources of information. The IPCC defines four sources of uncertainty that currently limit the detail of the regional projections:

1. ***Natural variability.*** Due to the limiting factor of observations (both in time and in space), we have a limited understanding of natural variability. It is difficult to characterise this variability and the degree to which it could exacerbate or mitigate the expected background change in climate. This variability itself could change due to anthropogenic factors, such as increases in the frequency of droughts and floods.
2. ***Future emissions.*** Much of future projected change, at least in terms of the magnitude of change, depends on how society will change its future activity and emissions of greenhouse gases. Even so, the world is already committed to a degree of change based on past emissions (at least another 0.6° C warming in the global mean temperature). Human responses to managing emissions could result in a projected global mean temperature change of between 1.5° C and 5.6° C.
3. ***Uncertainty in science.*** This is complicated within Africa because current understanding of the regional dynamics of the climate of the continent is limited. Aspects of the regional climate system could interact with globally forced changes either to exacerbate or to mitigate expected change, such as land use change. This could lead to rapid non-linear change, with unforeseen and sudden increases in regional impacts.
4. ***Downscaling.*** – "Downscaling" is the term used to define the development of regional scale projections of change from the global models (GC-MS) used to simulate global response to the climate system. Downscaling tools can introduce additional uncertainty when, for example, downscaling uses regional climate models as opposed to statistical techniques. Usually, this uncertainty limits the confidence in the magnitude of the projected change, with the pattern and sign of change often interpreted with greater certainty.

While the decision support system simulates the impact of climate change and of development on water discharge, linking this information directly to dynamic flood hazard mapping requires more accurate data than were available before the completion of the decision support system. Flood data could be generated for only two and 20-year return events and no data were available to simulate, for example, 50 or more extreme 100-year events. The completion of the decision support system allows the generation of flow data for these and many other events. A follow-on project has therefore been designed to expand the flood model and mapping results using the decision support system. Such results would allow for the zoning of risk and for the provision of regulations on where (and where not) to construct, how structures and assets should be constructed etc.

Flood modelling and mapping

Flood risk modelling (using the HEC-RAS model) and mapping were carried out for present-state and climate-change conditions in the main channels of the Zambezi, Pungwe and Limpopo in Mozambique. Figure 31 shows the model domains and flood extent for each river. Four flood inundation layers each were created for the Zambezi, Pungwe and Limpopo main channels: the baseline (from 1961 to 2000) two and 20-year flood events; and the climate change (from 2045 to 2065) two and 20-year flood events. The flood maps show where, under the assessed conditions and for a specific return event, there is a risk of flooding in a spatial context (with a 90 m pixel resolution).

Findings indicate that the larger catchments of Zambezi and Limpopo are more stable due to their size, while the Pungwe is strongly influenced by single sub-basins. In general, in the Zambezi, a slight decrease in flood frequency is predicted under climate change, which amounts to a decrease in flood flows by 2.8%. In the Pungwe and the Limpopo, an increase in flood frequency is predicted, leading to an increase in flows by 8.1% and 5.5%, respectively. Combined with the fact that the flows will become more peaky, this indicates more flood risk for the Pungwe and Limpopo basins.

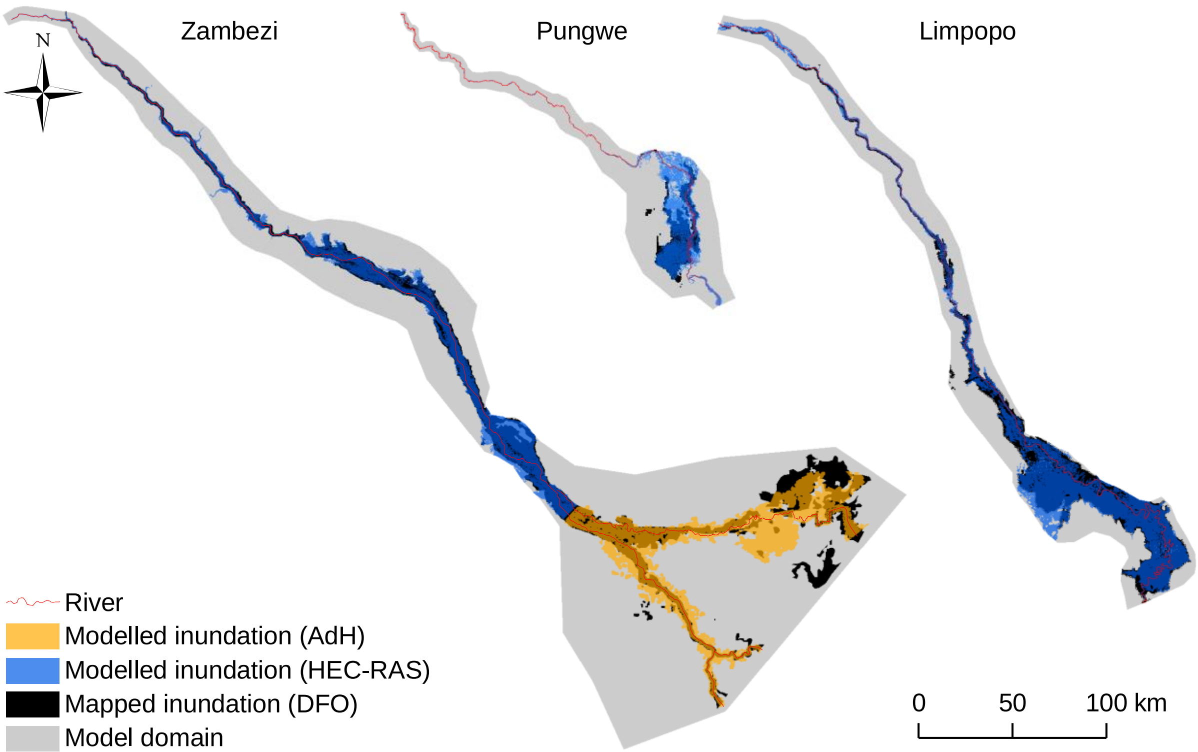


Figure 35: The three rivers: Mapped (black) and modelled (brown/blue) inundation

As can be seen from Figure 35, there is a reasonable fit between mapped and modelled inundation for the Zambezi and Limpopo and some overestimation in Pungwe (resulting in higher standard deviation).

Three cities and towns – Chokwe, Caia and Tete – were studied as close-up examples. Figure 36 shows the flood risk for Caia under climate change. For flood events returning every two and 20 years, the cities of Chokwe and Tete showed no discernible change in flooding under climate change conditions.

Analysis of other flood events (such as more extreme 50 or 100-year return events) has become feasible only with the completion of the decision support system and could show more differentiating results.

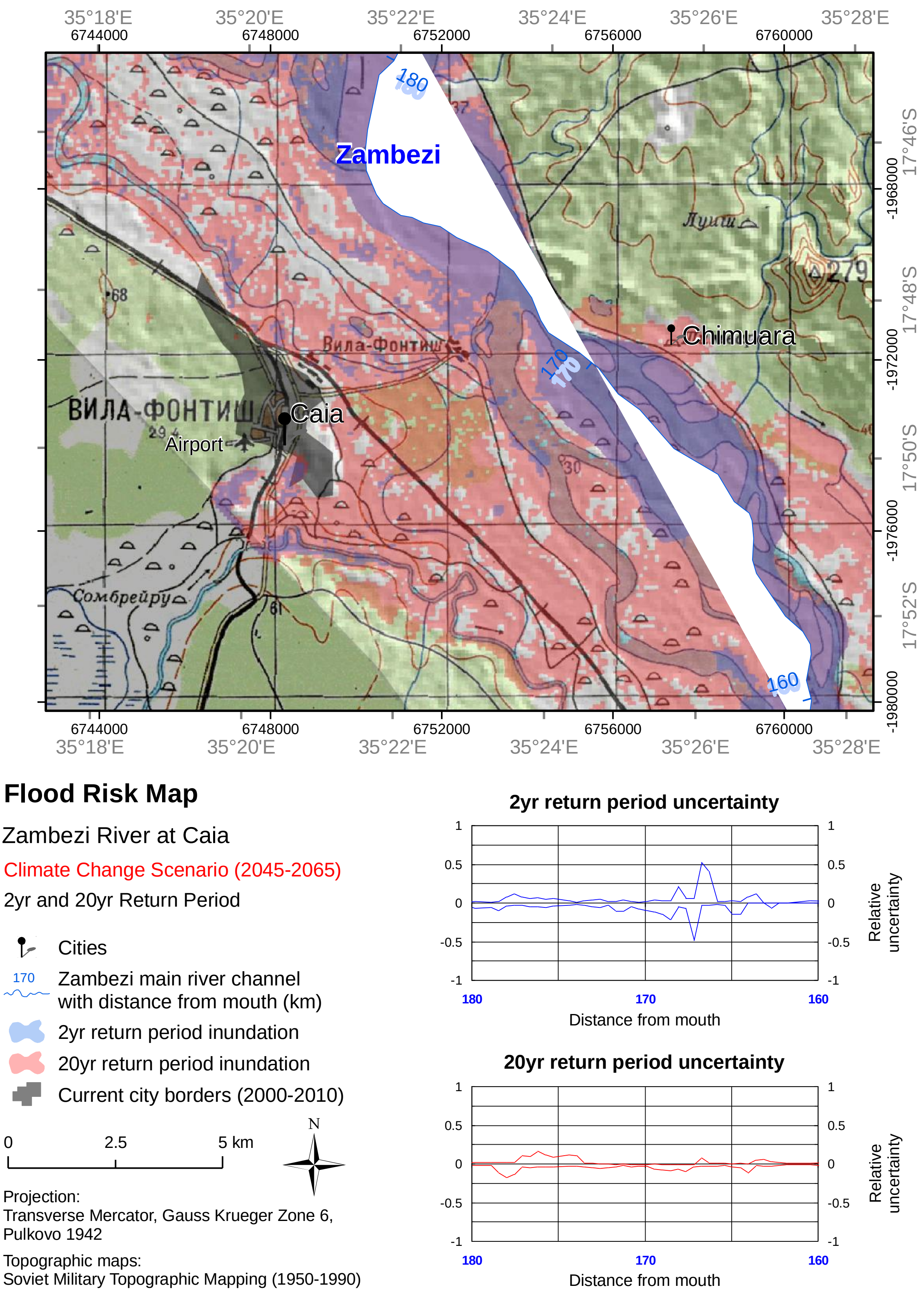


Figure 36: Zambezi River at Caia: Flood risk map for the two and 20-year return period climate change scenario

A similar analysis can be done for specific locations along the Limpopo and Pungwe rivers.

As can be seen from Figure 36, the red areas are flooded by 20-year return events and the blue areas are flooded by two-year return events. For floods with a return period of two years, changes due to climate change by 2045 to 2060 compared with the baseline are predicted to be marginal, with few and patchy differences around the city. For floods with a return period of 20 years, changes due to climate change by 2045 to 2060 compared with the baseline are predicted to be larger, potentially cutting off transportation infrastructure. The spatial flood extent of more extreme events (of a return period of 50 to 100 years, for example) under climate change compared with the baseline can now also be analysed with the completion of the decision support system.

Flood risk modelling was restricted by poor data availability for the setting up of one-dimensional and two-dimensional hydraulic models. Data improvement approaches were undertaken to enhance the plausibility of the digital elevation model and hydrological data were checked for plausibility. Despite these efforts, however, the inundation mapping includes uncertainties that require more detailed analysis for specific decision-making and infrastructure design purposes. While the results give an approximation of areas potentially at risk of being flooded under the assessed events, the data available restrict predictions regarding depth of flooding. This means that, while the maps can be used to identify risk areas, they cannot be used to identify safe areas accurately. Improvement in hydro-meteorological monitoring and in the observation network, including data processing and storage, is therefore essential for future endeavours by Mozambique to carry out detailed flood risk assessments and to plan river-related developments. Details on the necessary input data are contained in the main INGC Phase II report.

In terms of flood prevention, the present situation of defence measures can be described as follows:

- Upper catchments are strongly deteriorating, promoting increased run-off and more peaky floods.
- Operational rules for large dams are not targeted at flood retention with low operational levels but rather at maintaining high supply levels.
- Small dams and weirs along the tributaries are not numerous enough and are too small to play a significant role in flood retention.
- No land development policies that would prevent settling and construction in flood-prone areas are in place or enforced.
- The data and monitoring situation at the local level is not sufficient to conduct detailed flood risk assessments and gain thorough information on local flood conditions.
- Neither is a making-room-for-water concept with holistic approaches followed nor is the retention function of the floodplains for basin-wide flood prevention maintained; preference is, instead, given to local approaches.
- Structural defences are mostly not in place (these would likely be recommendable for only a few key locations).
- Monitoring and early-warning systems are not sufficiently in place.
- Preparedness activities and adaptation through flood-resilient construction are not promoted broadly but are, instead, carried out only locally by a few non-governmental organisations.

Various protection measures for achieving flood protection goals are discussed in the main INGC Phase II report, including unit cost estimates. A making-room-for-water concept, for example, is proposed to improve the flooding situation. While structural flood defences and assets are inevitable at the local scale for high-value locations, it is essential to understand that the occurrence of floods would be increased by the large-scale construction of defences, which would increase flooding downstream. Catchment conservation approaches, however, would have strong benefits not only by reducing flooding but also by equalising annual flow and increasing agricultural water availability. From a cost-benefit point of view, holistic and long-term catchment conservation-based approaches are therefore preferable to the construction of structural defences.

Any development plans in the water sector for Mozambique would need to focus on the baseline data situation and on the formulation and enforcement of planning guidelines on disaster response and on urban and rural development. The main challenge would be to conduct baseline data acquisition, including the setting up and running of the various monitoring stations and the setting up of competent regional and local departments to deal with the tasks on site.

Limpopo vulnerability analysis

A separate study combining socio-economic vulnerability analysis and flood analysis was undertaken to inform decision-makers that the Limpopo sub-basins show the highest probability of change in terms of flood risk, flow reduction and crop failure and to inform them which of these sub-basins are the most vulnerable socio-economically[19].

In this study, seven downscaled GC-MSs from the wetter downscaling and seven downscaled GC-MSs from the drier downscaling were applied to produce a total of 840 years of daily maps (14 downscalings of a 40-year control period and a 20-year future period). The climate scenarios were run through two hydrological models – the agricultural water-requirement satisfaction-index model and the geo-spatial stream-flow model – to determine where in the basin the impacts of climate change on water (floods and droughts) and on agricultural yield would be felt most. Overlaying these findings with the areas showing the highest socio-economic vulnerability generated the priority areas for the planning of climate-proofing interventions in the Limpopo River basin (Figures 37 to 40).

[19] The flood section (using HEC-RAS to model one-dimensional stream flows and inundation) described above is physically based and shows the risk of flood at a particular area, allowing for the development of flood-risk zones and recommendations on where not to build. The present analysis (using the geo-spatial stream-flow model), however, is statistically based and provides the average values of the entire sub-basin, helping decision-makers with overall planning and with the targeting of priority districts for more preventative activities.

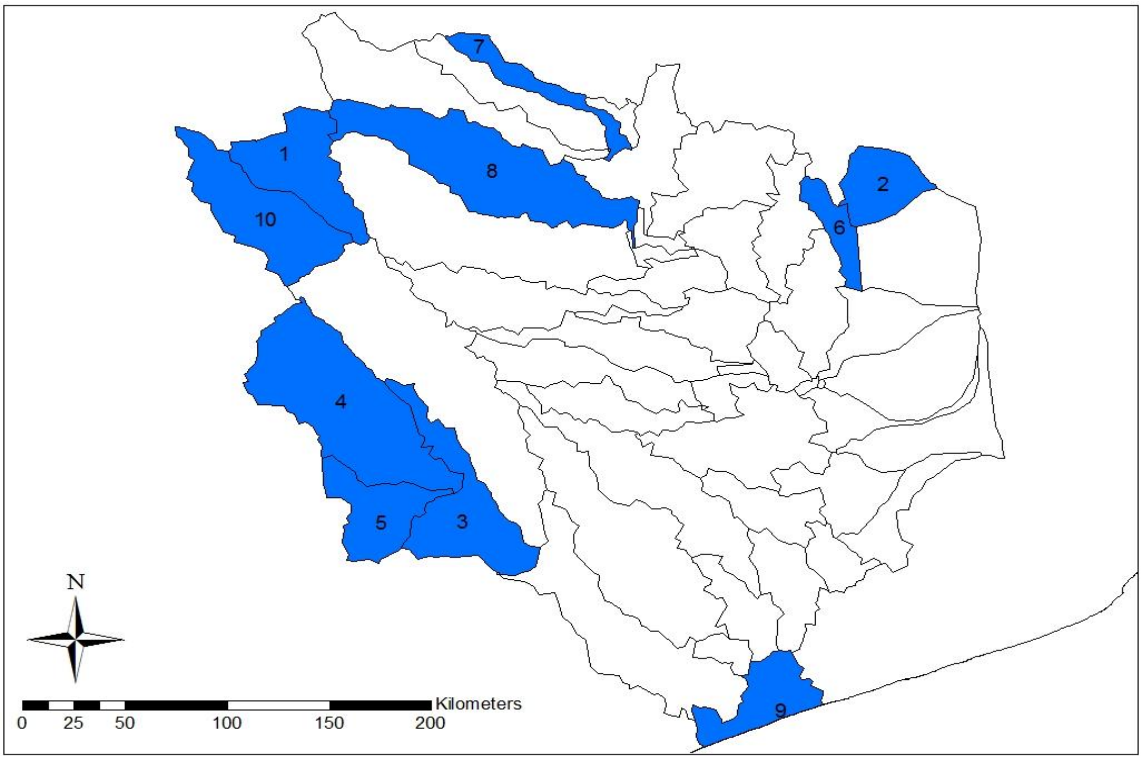
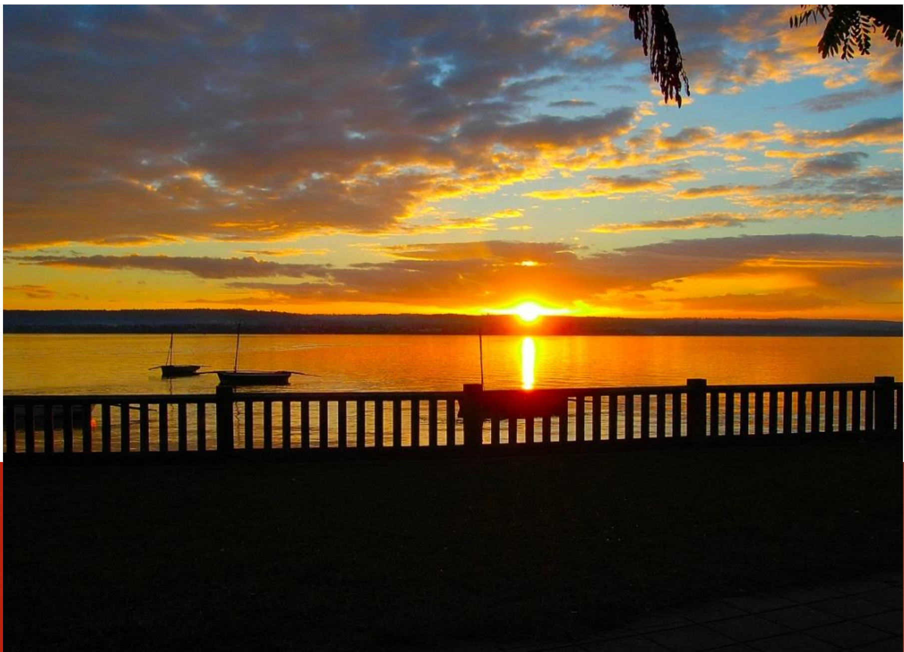


Figure 37: Limpopo sub-basins in Mozambique where the combination of increased risk in magnitude and in the frequency of flooding with social vulnerability is highest

As can be seen from Figure 37, the priority sub-basins are scattered around the perimeter of the basin in the west and south-west and in the north-east (in Funhalarouro District in Inhambane Province, ranked fifth in terms of social vulnerability).

Of the entire Limpopo River basin (2.9 million ha), some 21% falls within Mozambique, mainly in Gaza Province. The catchment area represents 11% of the total land surface in Mozambique and approximately 7% of its population.



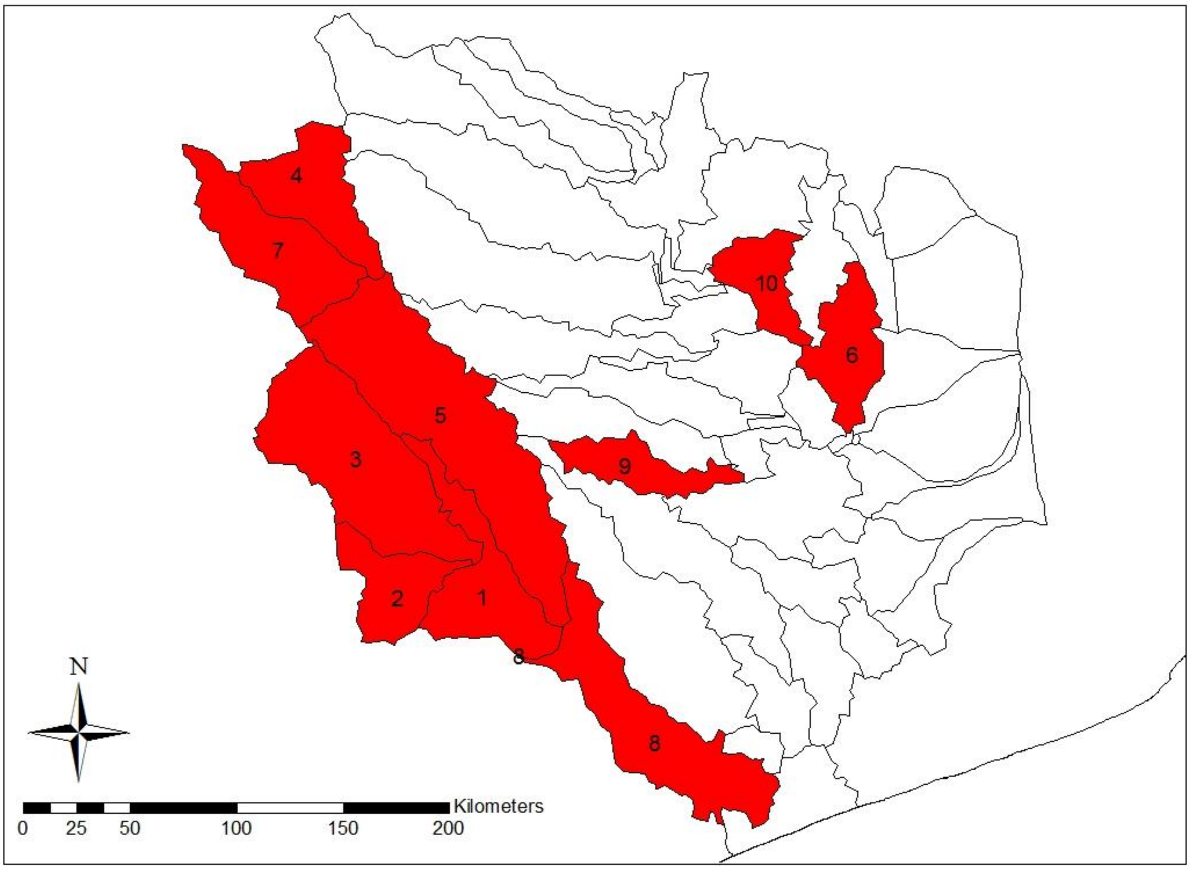


Figure 38: Limpopo sub-basins at risk from the highest decreases in flow, located predominantly in the south-west of the basin

As can be seen from Figure 38, this is also where the districts with the highest vulnerability index are located (in Massingir and Chicualacuala).Adaptation interventions here should focus on countering the impacts of the projected decrease in flow.

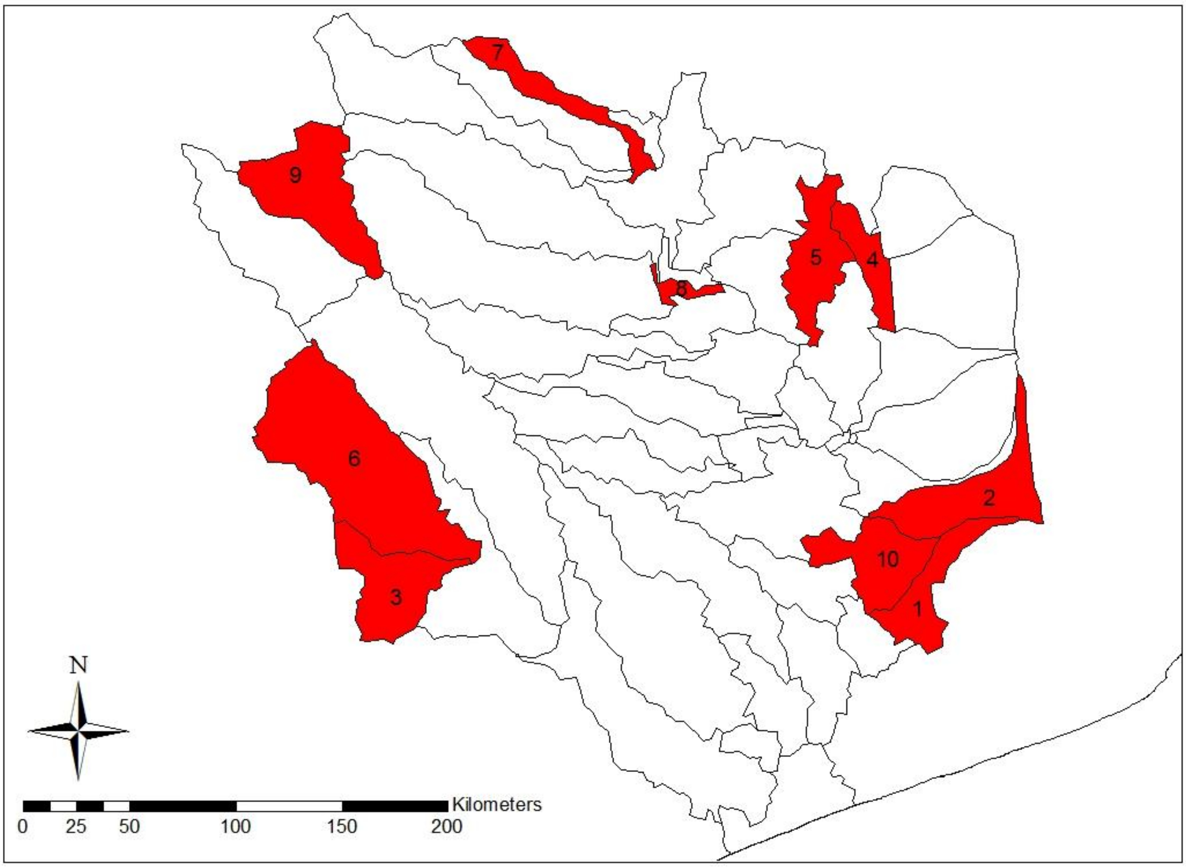


Figure 39: Sub-basins with the highest increase in probability of crop failure during the October-November-December planting season

As can be seen from Figure 39, the two priority sub-basins with high social vulnerability, high risk of crop failure and decreased crop performance (during October, November and December) are located in the south-east of the basin (in the Funhalarouro and Manjakaze districts).

The majority of the population in the Limpopo basin consists of rural, subsistence and poor communities that depend largely on the natural resource base (particularly on rain-fed agriculture) for their livelihoods20. These communities are also characterised by a generally high level of illiteracy, a high population growth rate and inadequate communication infrastructure21. The population has long employed a suite of indigenous strategies to deal with the low productivity of the basin but an increase in population size has led to increased pressure on land and a shift to more intensive land use. Due to their dependence on the natural resource base, these communities are highly vulnerable to the impacts of climate change and their vulnerability will likely be exacerbated as the magnitude of climate change and of associated climate-related disasters increases.

Projected improvements in basin irrigation efficiency and capacity are expected to improve the irrigation situation in the basin by 2030. Under alternative climate change scenarios, however, conditions are expected to worsen significantly compared with the scenario for 2030 without climate change22.

[20] National Adaptation Plan of Action, 2007.
[21] 2010 estimate from www.cia.gov.
[22] Zhu, T. & Ringler, C. 2010. *Climate change implications for water resources in the Limpopo River basin.* Environment and Production Technology Division, International Food Policy Research Institute.

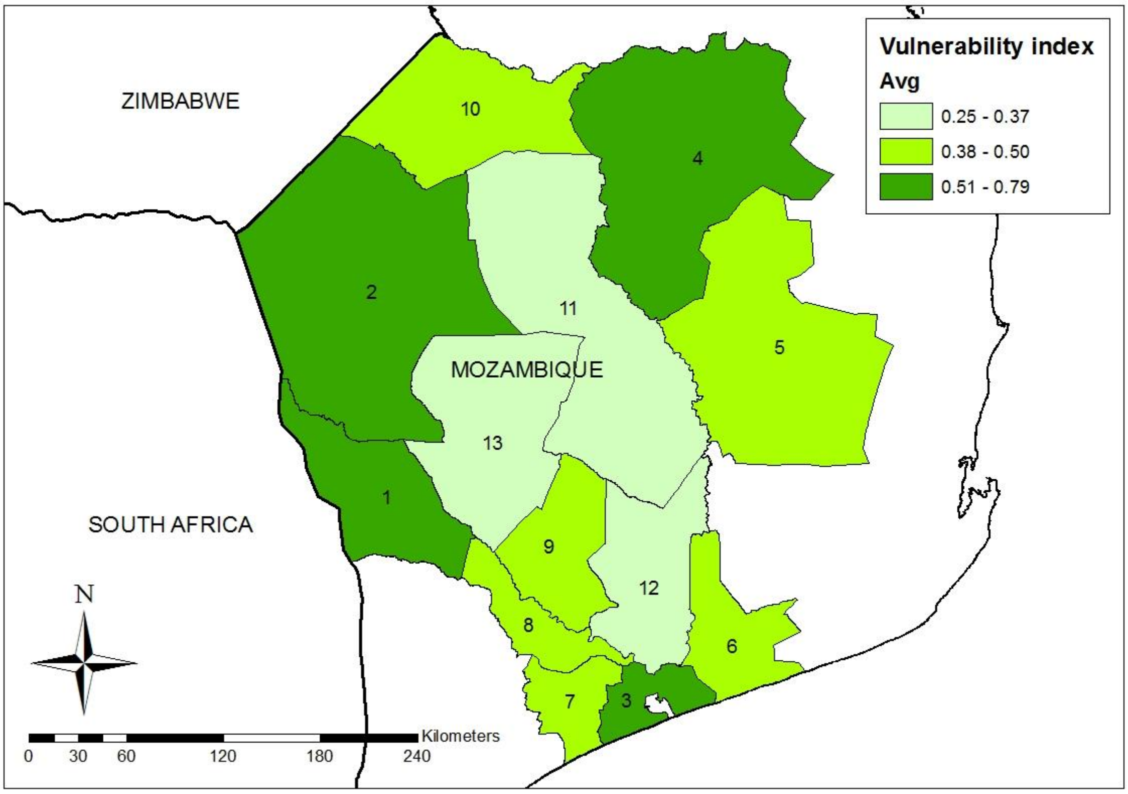


Figure 40: Mozambican districts in the Limpopo River basin: Vulnerability index

As can be seen from Figure 40, the determinants of vulnerability include financial assets, the availability of liquid capital, the dependency ratio, dependence on natural resources and reliance on social support. The indicators and methodology are described in the main INGC Phase II report.

In terms of overall social vulnerability, Massingir (1) is the most vulnerable district, closely followed by Chicualacuala (2) and Xai-Xai (3). The districts with relatively lower levels of social vulnerability are Mabalane, Chibuto and Chigubo (11, 12 and 13). These do not necessarily have low absolute social vulnerability but, rather, are slightly better off compared with other districts in the Limpopo basin. Massingir is among the three most vulnerable districts in three component indicators: the value of cattle; the mass of grain received in the last year; and the value of non-farm income. It also features as fourth most vulnerable in terms of spending on food as a proportion of total income.

Analysing the composition of vulnerability within each district has important policy implications, as it highlights where interventions would be best placed for adaptation to changing climate. The index shows current social vulnerability, which holds if climate change or climate extremes occur at present. This should be updated (ideally annually) to capture temporal shifts.

Maputo urban-drainage case study

The urban drainage situation in Maputo is problematic, with several neighbourhoods in the city experiencing frequent flooding subsequent to high-intensity rainfall events. With climate change projected to increase rainfall variability and intensity, urban flooding, already identified by the municipality as the priority hazard to address in the city[23], is likely to worsen. An in-depth study of the drainage problem in a specific area[24] in Maputo (this area is shown in Figure 41) was conducted and potential solutions were identified.

Figure 41: Maputo: Position of the selected sub-catchment

The sub-catchment is located around the Praça dos Heróis, with Maputo International Airport neighbouring to the west. It is a sub-urban area with a high population density, with partially unplanned and informal infrastructure, with no waste-water sewer system and with an incomplete storm-water drainage system. Due to intensive housing in the catchment area, the infiltration rate of water in the entire sub-catchment is very low. Most of the precipitation contributes directly to the discharge in the storm-water channels as surface runoff. The local population of Maxaquene confirmed that flooding is frequent in their neighbourhood, with considerable flooding occurring approximately twice a year. While it is difficult to distinguish how much of the flooding is due to anthropogenic factors (insufficiently controlled development) and how much is due to climate trends, it is clear that the worst events of erosion and flooding are related to extreme rainfall, which is expected to become more variable and intense under climate change.

[23] INGC Phase II Preparing Cities report

[24] Due to data scarcity, stakeholders (Ara-Sul, the DNA, UNHabitat, the Eduardo Mondlane University Maputo, the Municipal Directorate for Urban Planning and Environment and the INGC) agreed to an in-depth study of a selected sub-catchment of the city comprising Bairro Maxaquene A and Bairro Mavalane A, which already experience frequent and heavy flooding.

Figure 42: Street crossing of Joaquim Chissano Avenue with Acordos de Lusaka Avenue: Joint of three open channels

The open storm-water drainage channel that collects all the storm-water from the secondary system in the neighbourhood can be seen in Figure 42. The yellow circle marks the outlet of the modelled sub-catchment and the red circles mark culverts. The confluence of storm-water from three directions at this one point, in combination with insufficient culvert and channel capacity (and a considerable amount of blockage), is responsible for flooding in all three channels.

The flooding reduces the road's bearing capacity and effective lifetime, poses a safety risk and restricts access due to road closure. The expected trend of more intense rainfall episodes will aggravate the situation. To resolve both the upstream and the downstream flooding, a combination of cleaning and sustainable drainage systems (SuDS[25]) is recommended.

To capture the potential effects of climate change on flooding in the selected sub-catchment area, different future scenarios and possible flood mitigation measures for the area were simulated with a detailed hydraulic model using SWMM5 software. Training was provided to stakeholders to facilitate the replication of the analysis in other sub-catchments in Maputo.

The model results showed that cleaning the downstream culverts but not the upstream channels would not reduce the total flooding by much, even though the water quantities inundating the studied

[25] The main purpose of SuDS is to mimic the natural drainage of a site before development. This is achieved by capturing rainfall and allowing as much as possible to evaporate or soak into the ground close to where it falls. The rest is directed to the nearest watercourse to be released at the same rate and volumes as before development. Hard-engineered elements are often used in high-density, commercial and industrial developments and include permeable paving, canals, treatment channels, attenuation storage and soakaways. SuDS will become increasingly important in controlling surface water if rainfall increases because of climate change.

catchment area would reduce somewhat. Addressing the main problem, namely the blockage of the main upstream channel, would lead to increased discharge capacity in the channel and more flooding concentrated at the outlet of the sub-catchment (the yellow circle in Figure 42), where the culvert is too small. Increasing the culvert diameter by 50% would help but only if the subsequent culverts in the main channel along Joaquin Chissano Avenue were also widened.

The calculated impact of a climate change scenario will be fairly directly related to the assumed increase (or decrease) in rainfall intensity. A simulated rainfall intensity increase by 20% in the selected sub-catchment area leads to a similar percentage (20%) increase in runoff. Different rainfall intensity increases were modelled to confirm this direct relationship. The explanation is that relatively small-scale effects, such as interception and micro-retention, and slower processes, such as infiltration and evapo-transpiration, play a minor role in the modelling of storm-water runoff in urban areas after extreme events. In relatively small catchment areas, such as the modelled area, routing effects can also be neglected (the distance between where the raindrop falls to the point where it enters the next storm-water drainage channel).

In conclusion, it can be said that the structural and maintenance shortcomings of the drainage system have the largest negative effect on the urban drainage situation and that the more extreme weather events expected from climate change will worsen the conditions. Bottleneck improvements should take climate change impacts into consideration. Box 6 summarises the recommendations.

Box 6: Maputo case study: Measures to address urban flooding

1. ***Improved maintenance of the existing urban drainage system*** (at an estimated cost of US$640 000):
   - Elaboration of a digital urban drainage-infrastructure inventory.
   - City-wide cleaning campaign of all urban drainage and sanitation infrastructure.
   - City-wide information campaign to raise awareness of urban drainage and solid-waste management and of the prevention of the blocking of drains.
   - Elaboration and implementation of a detailed operation and maintenance plan for urban drainage and sanitation infrastructure.

2. ***Recalculation and redesign of the urban drainage system*** (at an estimated cost of US$520 000 to US$820 000):
   - New hydrological calculation of relevant design storms, incorporating climate change impacts, ideally based on information of newly installed hydrometric precipitation measurement devices.
   - One and/or two-dimensional steady-state and non-steady-state flow calculation of open channels.
   - Steady-state and non-steady-state hydraulic calculation of piped storm-water and waste-water sewers.
   - Detailed city-wide network calculation of the entire sewer and drainage network (with, for example, the SWMM5 model).
   - Ground-water recharge through infiltration as the most sensible storm-water reuse mechanism.

3. ***Structural measures*** (at an estimated cost of US$50 000 to US$500 000):
   - Extension and reconstruction of culverts based on the results of a city-wide hydraulic model.
   - Concept, design and implementation of low-impact measures.
   - Finalisation of the storm-water retention basin in northern Sommerschield.

4. ***Other recommendations***:
   - Integrated land use and settlement master plan for the whole city of Maputo (including Matola and suburbs), with a redesign of existing informal settlements in a more structured manner to allow for the installation of basic infrastructure.
   - Concentration of ownership and responsibility for the operation and maintenance of urban

drainage infrastructure with one institution.

4.4 THEME III D: FOOD SECURITY: MEETING DEMANDS

"Climate change, which is taking place at a time of increasing demand for food, feed, fiber and fuel, has the potential to irreversibly damage the natural resource base on which agriculture depends. The relationship between climate change and agriculture is a two-way street; agriculture contributes to climate change in several major ways and climate change in general adversely affects agriculture." – IAASTD[26] Synthesis Report, Art. 4.1, 2008

Most food-crop agriculture in Mozambique is dry-land or rain-fed agriculture, which means that it is completely reliant on precipitation and resonant soil moisture to satisfy crop water demand. In times of drought, precipitation is infrequent and soil moisture is low, thus increasing water stress during crop growth and severely reducing crop yield. High temperatures can also effectively decrease crop yields independent of water availability. If drought conditions coincide with abnormally high temperatures, crop losses are very likely.

Box 7: Changes in temperature and rainfall in Mozambique: Historical trends and future projections (INGC, 2009)

- Increase in temperature is already apparent across Mozambique, much of this increase occurring since 1990.
- There have been no obvious changes in mean rainfall during the 1960 to 2000 period, although there has been noticeably higher inter-annual variability in the southern and central regions.
- In the event of insufficient global mitigation results (too little, too late), temperatures in Mozambique could rise by as much as 2 °C to 2.5 °C by 2050 and 5 °C to 6 °C by 2080. Rainfall variability will increase and there will be shifts in the start of rainy seasons, there will be wetter rainy seasons and there will dryer dry seasons.
- The highest temperature increases will occur inland away from the coast and during the September-November period (up to +2.5 °C to +3 °C in maximum temperature by 2046 to 2065). Highest increases in minimum temperature (+2.5 °C to +3 °C) are observable over the Limpopo and Zambezi valleys, also during the September-November period.
- There will be an increase in the likelihood of extreme maximum daily temperatures (above 35 °C) of approximately 7% by 2046 to 2065 and 25% by 2080 to 2100 over all regions.
- Changes in rainfall are much harder to detect due to the spatial and temporal heterogeneity of rainfall. Downscaled projections from seven GC-MSs suggest an increase in December-May rainfall by 2046 to 2065, with the highest increases towards the coast and smaller increases inland. The spread between models, however, is large, with some models suggesting rainfall decreases. Increases in rainfall will likely be greatest towards the end of the summer season, especially in the northern and central regions.
- Increases in evaporation will likely be greater than increases in rainfall during winter and early summer (from June to November) over all regions, resulting in a drier dry season. This is especially apparent over the central region.

[26] International Assessment of Agricultural Knowledge, Science and Technology for Development.

The agricultural sector is crucial to the development of Mozambique. The government's strategic plan for the period from 2011 to 2020 calls for an average annual growth in crop production by 7%, which should be achieved by doubling crop yields by 2020 and increasing the cultivated area for the most important crops by 25%, guaranteeing, at the same time, a sustainable use of natural resources.

In Mozambique, the gap between actual and potential yields remains very large[27] but significant increases in yields should be attainable with the intensification of agriculture and technological development. The present analysis shows that climate change poses a threat to government goals, as the impacts of climate change will demand significantly more effort to attain the targeted levels of yield. Changes in temperature and rainfall will affect yield, as will ground-level O_3 (explained in subsequent sections). Fresh-water resources, on which the viability of agriculture depends, are vulnerable and strongly impacted by climate change, with present water management practices not sufficiently adapted to cope with these impacts (FAO, 2008a; INGC Phase II, 2012). Crop yields could also decrease substantially across Mozambique due to an increasing frequency and intensity in natural disasters (particularly due to droughts affecting the semi-arid and arid regions of the country), due to floods affecting the rich valleys of the rivers, where population density and economic activities are concentrated, and due to cyclones affecting the coastal zones of Mozambique, where the majority of people live.

As a consequence of these impacts, climate change is likely to aggravate food insecurity in Mozambique, putting at risk the country's efforts to reduce poverty. It is therefore crucial to start implementing adaptation measures to reduce the impacts of climate change and increase agricultural productivity.

Over the past five years, a number of studies have tried to model the impacts of climate change on crop yield in Mozambique[28]. Results vary by approach used and by crop but, generally, indicate an overall slight decrease in crop yield on average at the national level, with pockets of stronger decrease and some pockets of increase, depending on crop type and geographical area. INGC Phase II, applying a very robust methodology involving seven general circulation models and the Clicrop crop model for six crops in Mozambique, found yields for maize under rain-fed production to decrease by 11.1% of present yield by 2046 to 2065. This is followed by soy beans (with a projected 6.4% decrease by 2046 to 2065), groundnut (with a 4.6% decrease), cassava (with a 4.2% decrease), sorghum (with a 3.5% decrease) and cotton (with a 2.9% decrease). On average, annual crops lose approximately 5.4% in yield with each degree Celsius increase in average temperature. Perennial crops, such as sugar cane, cassava and fruit trees, should show a slight increase in yield (with more production of green material), all other factors remaining constant.

Despite the more sophisticated crop models and higher number of climate models (GC-MS) used, overall results continued to show less impact on yields than expected based on actually observed yield losses.
Figure 43 shows the geographical spread of the projected impacts for maize by 2046 to 2065 based on water and temperature as main factors. Annex 7 shows the impacts by geographical area for the other crops.

[27] For a detailed analysis, see the INGC Phase I synthesis and agriculture reports, 2009.

[28] For example: INGC Phase I, 2009; Mozambique Economics of Adaptation to Climate Change, 2010; Mozambique: Economic Vulnerability and Disaster Risk Assessment, RMSI, 2009; MICOA National Adaptation Programme of Action, 2007; *MICOA Avaliação da Vulnerabilidade e Adaptação dos Sectores Económicos e Sociais às Mudanças Climáticas*, 2011.

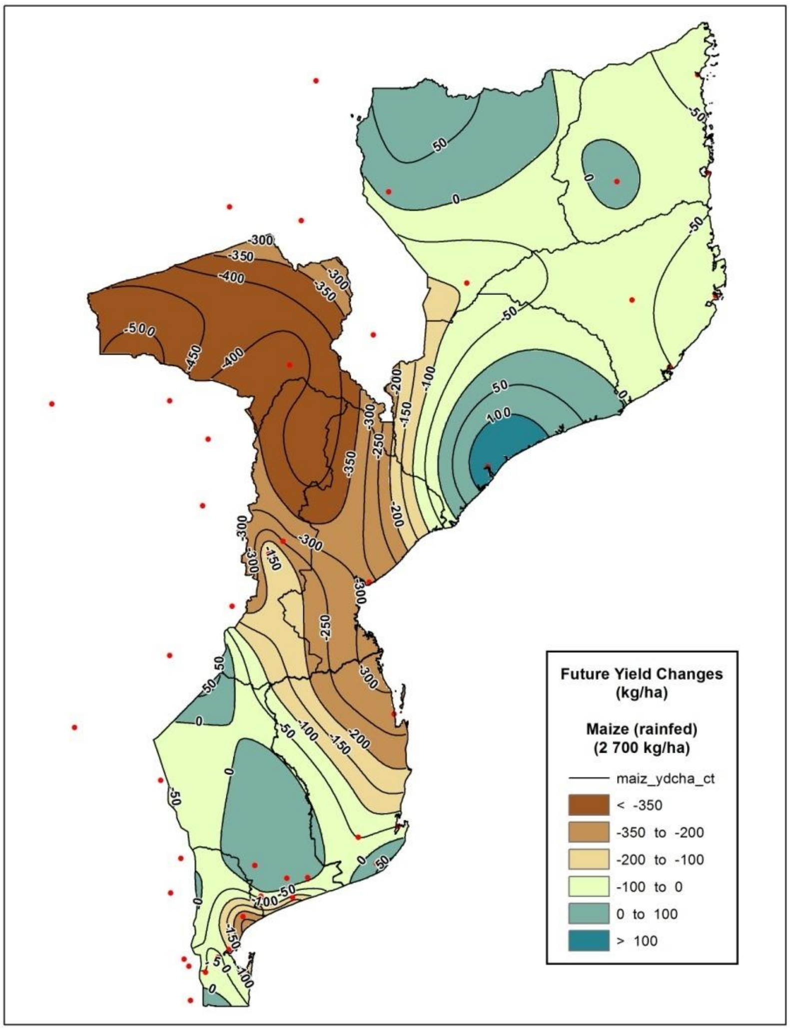


Figure 43: Expected changes in the future (2046 to 2065) for maize (expressed in kg/ha) under rain-fed agriculture based on the median of all seven climate change models (GC-MSs) and considering changes in temperatures and rainfall

As can be seen in Figure 43, the overall projected reduction is in the order of 11.1% of present yield. A reduction in crop yield in the order of 350 kg/ha or more is expected for rain-fed maize in Central Mozambique along the Zambezi valley (assuming a maximum rain-fed yield of 2 700 kg/ha with low input). The affected area stretches towards the Punguè and Buzi basins and part of the Save basin towards the coast of Inhambane, where the expected reduction reaches the order of 100 to 350 kg/ha. Slight increases are expected around Quelimane (up to 100 kg/ha) and in the northern interior (with 0 kg/ha to 50 kg/ha around Zavala). Light decreases in yields (with 0 kg/ha to 50 kg/ha) are expected in the rest of the country. The future water balance for maize is expected to be more negative overall (with a 7.8% increase in water deficit and a 4% increase in potential evapo-transpiration during growth).

Studies for Mozambique to date have assumed crop transpiration (water) and temperature to be the main restricting factors for yield. While water availability and temperature are important factors for yield, it was found that there is an essential additional factor that determines upper yield limit. It appeared that, in many cases, this had a much higher impact on yield than water and temperature– yet was not reflected in any of the models. This factor is ground-level O_3.

In broad outline, the relationship between ground-level O_3 and yield is as follows[29]:

- O_3 pre-programmes the maximum attainable level of the carbon-use efficiency (CUE) of a plant.
- More than 90% of a plant's dry material is derived from CO_2. CUE is the ratio between carbon actually sequestered or "fixated" by a plant and carbon captured through photosynthesis. When a plant is stressed by, for example, drought, CUE and therefore growth decrease as the plant uses part of the energy that it captured to fight stress, essentially, to survive.
- A high O_3 concentration at the start of a plant's life lowers the upper limit of its CUE, thus permanently decreasing the yield potential of the plant throughout its life. No matter how much irrigation and fertilisation the plant receives subsequently, its maximum yield remains substantially lower than its potential yield.
- A low O_3 concentration in the early phase of a plant's life leads to a relatively high CUE upper limit and therefore to a high yield potential of the plant throughout its life. If the plant is stressed (by, for example, being starved of water), its CUE and therefore its growth and eventually its yield decrease but, when the stressor is removed (when the water supply is restored in the case of the example), the plant's CUE is restored and it therefore grows more efficiently again due to the higher upper limit of its CUE.
- *The effect described above may lead to a large gap between average potential yield and average actual yield.*
- *This phenomenon is also likely to occur in Mozambique, especially where the burning of vegetation prior to sowing leads to the formation of high O_3 levels in the air.* The occurrence of this during the early phase of a plant's life leads to a low average CUE (of the crop) and therefore to low attainable yield levels.
- Low CUE furthermore means that plants (including natural vegetation) and their soils remove and store significantly less carbon, in other words, they remove less CO_2 from the atmosphere.

The potential implications of the relationships described above are highly relevant to Mozambique's goal to double yield in the coming decade, while taking into consideration projected climate change impacts.

The following were therefore decided on:

[29] The theory underlying this relationship was successfully reviewed by the Agricultural University of Wageningen, the Netherlands, in 2010 at the instruction of the Dutch Ministry of Agriculture. In the course of 2011, the concepts were explained to and well received by a group of professors at the Eduardo Mondlane University Maputo, the Technical Council of MINAG, the Coordinating Council of MINAG, the National Institute for Agricultural Research and the CCGC, which decided that this knowledge should be transferred and verified as soon as possible and that demonstration and implementation should start immediately (CCGC, 19 September 2011).

i. To do further upgrading of the modelling of the impact of climate change on actual yields in Mozambique by including temperature, CO_2 and ground-level O_3 as separate factors. The individual outcome and the combined outcome on crop yield of (i) 550 ppm atmospheric CO_2, (ii) a 1.7° C to 2.4° C temperature increase and (iii) a 15 ppb to 30 ppb ground-level O_3 increase, as associated with Mozambique's mid-century climate change, were therefore explicitly calculated. This layered approach facilitated the evaluation of the impact of the individual factors on their contribution to yield change, which allowed for the prioritisation of adaptive measures that focus on mitigating the impact on present and potential crop yield of changes in:
   - rainfall;
   - temperature; and
   - ground-level O_3.

ii To undertake a demonstration project in Caia in Sofala Province and Mabote in Inhambane Province to demonstrate the above relationship, essentially by planting under low, medium and high O_3 conditions, keeping other factors constant and comparing yields. The demonstration projects will show farmers how significant increase in yield is attainable through relatively simple adaptation options feasible in the Mozambican context. Planting started in 2012 and testing will run through 2013 to ensure robust results.

Table 4 summarises the expected impacts of each factor for the period 2046 to 2065 under climate change for six different crops and different factors. Increase in O_3 concentration is the factor with the most negative impact on yield, followed by increase in temperature. Increase in CO_2 concentration under climate change mitigates negative impacts but does not fully compensate for them.

Table 4: Modelled effects of climate change (changes in precipitation, temperatures, CO_2 and O_3) on crop yield for the 2046 to 2065 period

Crop	Precip. and temp.	Temp.	CO_2	O_3	Total
Cotton	-2.9%	-11.0%	+27.0%	-37.0%	-23.9%
Ground-nut	-4.6%	-11.0%	+10.0%	-14.0%	-19.6%
Cassava	-4.2%	+6.0%	+10.0%	-14.0%	-2.2%
Sorghum	-3.5%	-11.0%	+7.0%	-9.0%	-16.5%
Maize	-11.1%	-11.0%	+7.0%	-9.0%	-24.1%
Soy bean	-6.4%	-11.0%	+20.0%	-28.0%	-25.4%
Average	-5.5%	-8.2%	+13.5%	-18.5%	-18.6%

The impacts presented in Table 4 are the average results for the entire country, which mask variations from region to region. In the case of maize, for example, yield in the Tete area could decrease by as much as 45.0%. This decrease spreads from the Tete area towards the Sofala coast and towards the south. Yields could further decrease due to the projected increase in the frequency and intensity of disasters described elsewhere in this report.

The Strategic Plan for the Rural Sector Development (PEDSA 2011–2020) demands a doubling of yield by 2020, in other words, a 100% increase. The above findings demonstrate that, with climate change, it is necessary to target an increase in yield of 150% by 2020.

The implications of these findings, currently being demonstrated at two sites, are that significant improvements in yield appear to be attainable, some without high-level technology and skill requirements. Improvements can be achieved through the following adaptation measures:

- Adjusting sowing and planting dates to avoid high O_3 levels. This may require the use of suitable plant varieties and of irrigated instead of rain-fed agriculture.
- Changing to crops that are less sensitive to high temperatures or high O_3, such as cassava and sugar cane (crop selection).
- Undertaking soil analysis and correction, including in respect of zinc, selenium and sulphur, to improve anti-oxidant capacity.
- Using micro-organisms and soil fertility management to increase tolerance to high O_3.
- Breeding crop varieties that are more tolerant to high O_3.
- Investing in small-scale water harvesting infrastructure. There is great potential for poverty reduction using small interventions in rain-water harvesting and storage in smallholder settings in semi-arid and sub-humid areas. Typically providing 1 000 m^3 of extra water per hectare per season for supplementary irrigation will improve farmers' resilience to dry spells and, in combination with improved soil, nutrient and crop management (dealing with the O_3 factor), can substantially increase the productivity of small-scale rain-fed agriculture.
- Developing community-based small-scale irrigation, improving existing irrigation systems and developing new irrigation systems.
- Avoiding hot combustion processes, such as wild fires, and switching to cold fires to avoid high NO_2 emissions and the consequent occurrence of O_3.

Water management remains key, as climate change combined with development and population growth will increase demand for water, which is becoming less and less available. This will require the adoption of water storage mechanisms at plant level, community level and water basin level, thus improving water-use efficiency ("more crops per drop") to cope with increasing water scarcity.

Massive development and the adoption of adaptation mechanisms in the agricultural sector are crucial to increasing the resilience of Mozambican communities and society to climate change. This will require strong coordination mechanisms in the sector, the development of local adaptation measures and fast dissemination mechanisms involving both the private sector and large producers as well as small-scale farmers. It will require strong leadership from the government and a coordinated channelling of efforts and resources by all relevant sectors (universities, research institutions, policy-makers, extension services, and producers) towards the same goal of increasing agricultural productivity and resilience to climate change.

4.5 THEME III E: ENGAGING THE PRIVATE SECTOR

"Business simply cannot function if ecosystems and the services they deliver – like water, biodiversity, food, fibre and climate regulation – are degraded or out of balance." – Björn Stigson, President, World Business Council for Sustainable Development (WBCSD)

"Those businesses that have implemented effective risk management strategies or have competitively positioned themselves will be more adaptable and could stand to benefit from climate change. Those that fail to recognize the risks and potential opportunities may suffer decreased operational efficiencies and profit margins. Corporate responses to climate change should incorporate uncertainty regarding the nature, extent and location of change." – Earthwatch Institute[30]

With the above in mind, this theme looked at how the private sector can contribute to building resilience to climate change in Mozambique. The hands-on experience gained provides empirical feedback that supports the assumption that, if the private sector is engaged as a corporate citizen and takes steps to find solutions to future climate risk, it can be part of building a more sustainable society and so benefit from adaptation.

Private-sector investment in land depends on a number of strategic issues, many of which are vulnerable to climate change. Such issues include strategic location (for markets and transport), water resources, the availability of arable land, social and environmental conditions, infrastructure and disaster risk. Investment is therefore sensitive to varying degrees of climate change impacts, whether the sector is, for example, tourism, agriculture or forestry.

For targeted decision-making, investors want to know to what degree changes will occur in the sector and geographical area of their interest and what climate change means in terms of cost of production and supply and demand, especially in terms of ecosystem services (water, food and energy security). Even the most advanced downscaled climate change modelling, however, still deals with too much uncertainty to quantify such information at local level with the accuracy required by investors. The information generated may therefore serve general awareness creation and strategic planning rather than targeted decision-making.

On-site multi-disciplinary vulnerability assessment (both quantitative and qualitative) and mapping, however, are tools that can be used to indicate the localities of highest vulnerability to climate change and to indicate whether the services required for the investment are in sufficient supply to develop the business.

The case study for Cabo Delgado, described in the main INGC Phase II report, illustrates that climate proofing of investment plans can be effected by using tools and methodologies already available. This requires the mapping and high-value conservation labelling of the geographical areas that surround a project. Collaboration and recognition of these values between investors and civil society determine the level and cost of resilience and adaptation.

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[30] International Union for Conservation of Nature; WBCSD; World Resources Institute. Issue Brief I Ecosystem Challenges and Business Implications, November 2006.

The process in Figure 44 summarises the steps, analyses and tools used to arrive at the level of information required for targeted vulnerability mapping and decision-making. Many data of use to the private sector in this process already exist and are being pooled into an information portal to be managed by the Centre of Knowledge on Climate Change in Mozambique. Other data, however, are still unavailable or scattered in different institutions and need to be collected and organised.

PROCESS	DATA ANALYSIS	METHODOLOGY
BASELINE & TRENDS	• Description of pilot geographical area • High Conservation Value • Climate Change Scenarios • Investment Climate	• Consultations • Geographic information Systems (GIS) • High Conservation Value (HCV) analysis
VULNERABILITIES & IMPACTS	• Vulnerability to climate change (exposure, underlying vulnerability and adaptive capacity) • Climate change impact	• Consultations • Strategic Environmental Assessment (SEA) • Ecosystem Supply and Demand Analysis
RISKS, OPPORTUNITIES & ADAPTATION OPTIONS	• Business risks and opportunities • Adaptation options for and with private sector	• WSCSB model for adaptation with private sector
ADAPTATION AND INVESTMENT PLANNING	• Win-win options • Adaptation investments	• Climate Proofing of investment plans

Figure 44: Blueprint process for the climate proofing of investment opportunities

Companies that want to invest in a specific geographical area and whose investment involves the sustainable development of land where communities already reside nearby may benefit most from the process summarised in Figure 44.

As mentioned, the process was tested and implemented successfully – by the private sector in renewable energy and organic sugar production – in a pilot adaptation project in Cabo Delgado.

Important steps in analysing the area include GIS mapping, high conservation value analysis, downscaled climate change impact analysis (including coastal impact) by local experts and through strategic environmental assessment involving all stakeholders and designed specifically to assess vulnerability and private investment adaptation options under various climate change scenarios. The tools work with and integrate local knowledge and expertise. The process takes approximately four *months and six multi-disciplinary experts to complete a geographical area of analysis of approximately 1.5 million ha.*

The strategic environmental assessment carried out in the previously mentioned pilot adaptation project was the first of its kind in Mozambique, being specifically designed to analyse the implications of climate change on business opportunities. It attracted the attention of the OECD's Development Co-operation Directorate and Development Assistance Committee in France, which had developed the OECD guidelines on strategic environmental assessment and climate change adaptation and which confirmed that this strategic environmental assessment was among the first globally to focus specifically on climate change.

The climate lens of the strategic environmental assessment was obtained by analysing the geographical areas of three downscaled climate change scenarios and four critical factors for decision-making. These are key critical uncertainties that determine either the success or the risk of proposed investment options and that require the engagement of all parties involved. The critical factors for decision-making identified in this case were private-sector investment attraction, local-community livelihoods, ecosystem services and high conservation values. Each critical factor for decision-making was studied for three downscaled climate change scenarios in terms of exposure, underlying vulnerability and adaptive capacity to climate hazards.

Figure 45 summarises key results of the analysis.

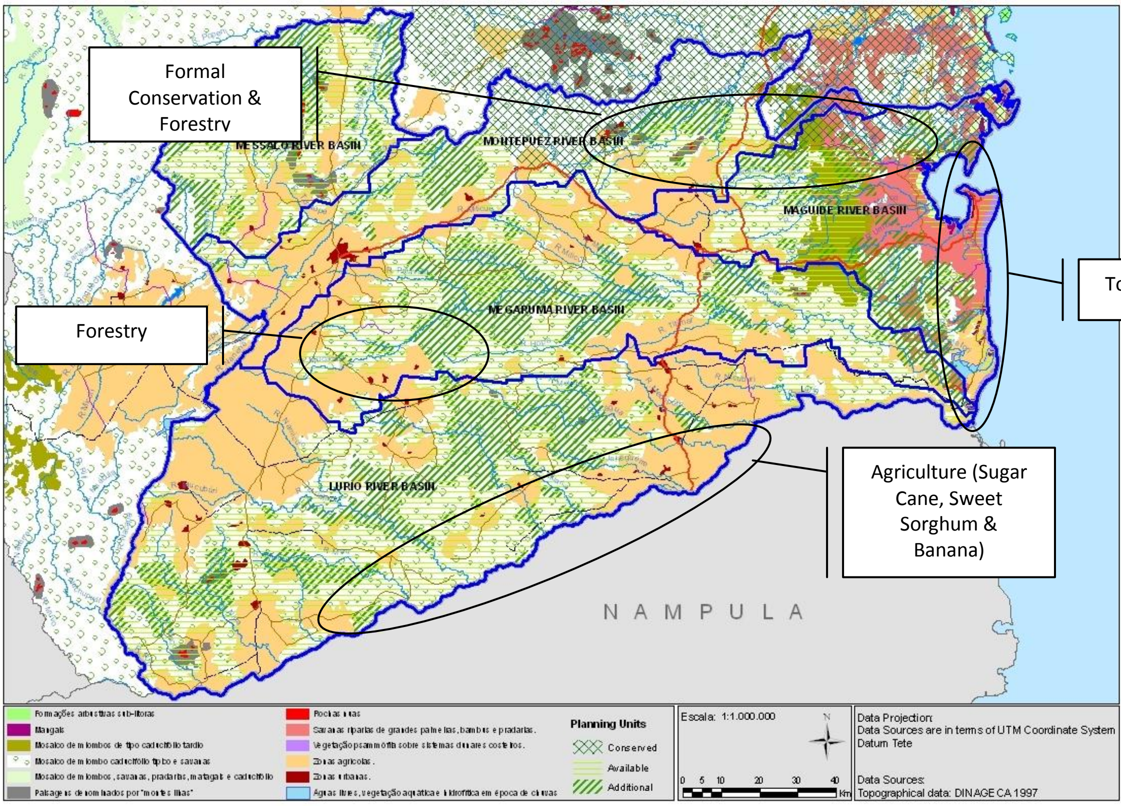


Figure 45: Sustainable investment opportunity map for the pilot geographical area in Cabo Delgado

The summary in Figure 45 is an example result of the blueprint process for the climate proofing of investment opportunities. For this pilot geographical area, some 5 469.8 km^2 (21%) were identified for additional conservation (depicted by the dark-green cross stripes in the figure) and 9 447.8 km^2 (37%) were identified as available for investment (depicted by the light-green horizontal stripes in the figure).

Investors want to know where the services that they require for their business or investment are in sufficient supply to provide them with the required opportunities to develop their business.

In the case under discussion, the process of incorporating the climate scenarios into a high conservation value analysis, GIS and strategic environmental assessment generated a map of the study area concerned. This map identified the areas that are both most suitable and best avoided for particular types of land use and investment and the areas that need to be conserved to satisfy ecosystem service supply and demand. These areas underpin livelihood securities and/or private-sector investments.

Based on such sustainable investment opportunity maps, in which environmental and climate change vulnerabilities are integrated, investors can conduct their own specific investment risk and opportunity analysis and formulate a portfolio of adaptation options, as illustrated in Figure 46.

The analysis is based on the series of risk and opportunity statements formulated for the sectors of agriculture, forestry and tourism that resulted from strategic environmental assessment and on a model suggested by the WBCSD. The latter states the following:

Business risks and opportunities resulting from climate change play a role in three spheres of activity and influence (WBCSD, 2007):

- Within company operations and supply chains (“within the fenceline”);
- in partnership with surrounding communities (“beyond the fenceline”); and
- in collaboration with the wider community (“beyond the horizon”).

“Within the fenceline” refers to opportunities for, risks to and operations for the private-sector company itself financed directly by the company. Opportunities “beyond the fenceline” usually benefit from a public-private financing mechanism and are harnessed in cooperation with surrounding communities and organisations. Opportunities “beyond the horizon” require involvement from the wider community and can affect the national, regional and international level.

Figure 46 shows the risks and opportunities and proposed portfolio of adaptation options for a planned private-sector investment[31] in bio-ethanol and sugar in Cabo Delgado Province. A similar exercise can be done for other planned investments in the area. All measures listed inside and beyond the fence shown in blue were carried out by the private-sector company during 2009 to 2011.

Example of climate proofing for bio-ethanol and sugar investment in Cabo Delgado	
Risks	**Opportunities**
Inside the fence	
• Seeds are washed away during heavy rainfall and replanting will be needed. • There is an increased risk of pest and disease, especially from birds (eating sweet sorghum seed), termites (eating sugar cane) and grasshoppers. • Prolonged dry spells increase the need and cost of irrigation. • Roads are inaccessible during the rainy season.	• There are opportunities for expansion with more degraded but recoverable land and water from the Lurio River becoming available. • There are opportunities to test new production techniques (e.g. a combination of sugar cane and sweet sorghum for bio-ethanol production). • Test more suitable drought and pest-resistant varieties. • Increase the supply of sweet sorghum through developing out-grower systems.
Adaptation options: Private financing	
• Select new varieties. • Irrigate. • Harvest water and conservation techniques. • Use pest control measures. • Develop out-grower systems for sweet sorghum.	
Beyond the fence	
Risks	**Opportunities**
• There is a shortage of water, firewood and energy. • The health of local communities (including employees) is at risk. • Roads are inaccessible. • There are potential land conflicts with the expansion of the crop areas of local communities and the in-migration of people from Nacala, which is more prone to cyclones. • Local communities are encroaching into riparian areas, which entails higher pest risk. • Competition for water from other large-scale	• Install extra water storage facilities and boreholes for local communities at a small extra cost. This will also improve relationships with the communities. • Sweet sorghum produced in out-grower centres is also an opportunity crop for local communities. • There will be diminished pressure on land and from subsistence farming because some of the population will turn to salaried employment. • Supply the local market with energy production means, e.g. bio-ethanol and

[31] EcoEnergia de Moçambique Lda is a Mozambican (98%) registered subsidiary of EcoDevelopment in Europe AB, a Scandinavian Agroenergy company based in Sweden with 30% shareholding in SEKAB AB, the leading European supplier of renewable fuel and the only supplier of certified bio-ethanol in Scandinavia. EcoEnergia aims to develop globally competitive, CO_2-optimal bio-ethanol and bio-electricity production, guided by the principles of ecological, social and financial sustainability. It has selected Cabo Delgado for its investment in sugar cane and other energy crops. The area for the pilot adaptation project comprised activities in the districts of Chiure, Pemba-Metuge and Balama in Cabo Delgado Province.

Example of climate proofing for bio-ethanol and sugar investment in Cabo Delgado	
investments will require lots of water. • Local communities are not changing their farming practices of slash-and-burn and rotation and are therefore taking more land from forests and wetlands, on which EcoEnergia also depends.	waste for briquette making. • Solar and wind energy can contribute to the public energy grid, increasing the availability of energy for other potential investors. • There is an opportunity for the conservation of protected areas. • Rehabilitate and install dams.
Adaptation options: Public/Private financing	
• Create awareness at community and local authority level. • Promote improved agricultural techniques. • Conserve riparian and other protected areas. • Install briquette-making infrastructure to turn factory waste into fuel. • Install solar and wind energy mechanisms. • Install water storage facilities and boreholes for local communities. • Maintain access roads. • Implement a well-designed social and environmental management plan.	
Beyond the horizon	
Risks	**Opportunities**
• There is a reputational risk of the degradation of land associated with monoculture. • There are accusations of land grabbing.	• Adapt investments. • Products can be certified and a premium price can be obtained. • Designed-in sustainability from the outset. • Use risk mitigation tools.

Figure 46: Climate-proofing private-sector investment in bio-energy and sugar and building resilience to climate change by local communities in Cabo Delgado Province

With business risks and opportunities resulting from climate change becoming clear from strategic environmental assessment and related tools, the most effective set of adaptation options could be identified. As can be seen from Figure 46, the measures were classified as being "Inside the fence", "Beyond the fence" or "Beyond the horizon" for the company, each category differing in reach and funding mechanism. The measures listed in blue were taken by the private-sector company during the pilot adaptation project. The measures listed under "Beyond the fence" were effected through joint financing by the private sector (60%) and government (40%).

The specific objective for this private-sector pilot adaptation project was to test the combination of sugar cane with sweet sorghum, a climate-resilient crop needing one-third of the water that sugar cane needs and able to sustain changes in temperature and evaporation and able to sustain longer dry spells. The project aims to (i) produce food as an added product to ethanol and (ii) maximise productivity by expanding the harvesting window and guaranteeing the continued operation of a planned distillery under conditions less suitable for sugar cane.

Five sweet sorghum varieties were tested at pilot sites (at Ocua and Chipembe) and on-farm trials were conducted in collaboration with local farmers (at Katapua and Bilibiza) in Cabo Delgado Province. The plants were monitored in terms of biomass, sugar content, juice content and general performance. The project also estimated the potential income of farmers compared with that of other cash crops and activities and assessed the grains of sweet sorghum for use as food.

Preliminary results indicate that sweet sorghum can be planted during the rainy season in December and January and harvested in March and April. Sugar cane can generally be processed from May to June when sweet sorghum is not available. Sweet sorghum can furthermore be rotated with sugar cane to obtain higher yields. In this way, total production can be increased and the factory can extend its operation time by six to eight weeks compared to a factory relying only on sugar cane. Sweet sorghum has advantages in that it requires much less water compared with sugar cane, it is hardier and can grow in soil where sugar cane struggles and it takes only four months to mature compared with 11 to 18 months for sugar cane. Shorter plantation time implies quick money for the farmers. The harvesting window for sweet sorghum in March and April can also bring in extra food and income during the lean winter months when opportunities for seasonal work are limited. As these months are becoming drier, however, some irrigation for the March and April window will probably be required in the not-too distant future.

The combination of sweet sorghum and sugar cane production will maximise the operation of the distillery (installed in 2011) and reduce the time of investment cost recovery. Other advantages include using sweet sorghum as a food crop (local communities indicated a preference for the white sorghum varieties over the brown and red ones) and turning sweet sorghum into syrup and storing it for sale later in the year when cash is needed.

More research and tests are needed to improve sugar and biomass content and establish the right time for seed collection. If sweet sorghum is cut and harvested at the time ideal for ethanol (when sugar content is highest in the stem), grain yield is only 2 tons per hectare. If, however, it is allowed to mature in the field, grain yield is 30% higher. Tests are now being conducted with fertilisers that could increase sugar content. If, moreover, the issue of sun exposure can be sorted out, sweet sorghum could be produced year round, which would generate approximately 7 000 litres of ethanol per hectare. Replacing sugar cane with sweet sorghum would also reduce water use by at least 50% and would involve more local farmers in production.

The implementation of adaptation measures by the private-sector company in Cabo Delgado Province during the pilot adaptation project led to the following five improved results in respect of preparedness for climate change at community level:

(i) Awareness creation about climate change and adaptation in respect of community leaders and the representatives of various stakeholder groups, representing three villages of approximately 8 000 inhabitants. Two larger meetings with 80 to 100 decision-makers and representatives were organised and several smaller group discussions were held (Figure 47).

(ii) In terms of income diversification, the first 25 people turning from subsistence farming to salaried work (full-time employment). With the installation of the sugar factory and distillery, this number will double.

(iii) In terms of water conservation, the first off-river water storage facility to be constructed between 2012 and 2013 near the Lurio River, which will provide approximately 4 000 people with more secure year-round access to potable and agricultural water.

(iv) In terms of food security, the identification of a new cash crop that provides higher revenues than the existing cotton and sesame seed. This will benefit approximately 8 000 people. Some 475 ha of degraded land and land with low-value vegetation is being rehabilitated and will be put to productive use, with due account of water and crop change projections resulting from climate change. The project has also switched from chemical use to organic production. A nutrition bank has furthermore been developed and solutions to general pest and disease attacks on local crops are being identified. These findings will benefit local farmers, since they will be able to produce the same type of nutrition banks for their crop-land areas.

(v) In terms of energy provision, the use of bagasse from sugar cane to cover future energy needs for the housing of employees, for the factory, for irrigation and for workshops. Co-funding for some of the costs of solar irrigation will be needed to provide surrounding villages with additional energy.

Benefits and incentives for the private-sector company in undertaking the adaptation measures include having a brand name that will stand up against competition and obtaining a premium price on the market for its products.

Figure 47: Community meetings at the private-sector pilot adaptation project

Figure 47 depicts two community meetings held at the private-sector pilot adaptation project in 2009 and 2010 to discuss the impacts of climate change, coping mechanisms and research results. Participants included the Permanent Secretary of Chiure, Chefes de posto, community leaders, representatives from women's and youth organisations, representatives from community councils, persons responsible for education and health, and traditional leaders from the 35 villages in the district of Chiure. The total number of participants amounted to 80 in 2009 and 97 in 2010.

The communities reported persistent changes in rainfall and temperature, with rain arriving too late and stopping too early, with heavy rains at the start of the rainy season and with dry spells in mid-season. They had observed a shift in the hot season, which is now tending to start earlier and to last longer, and, with the cold season, starting later and hence becoming shorter. Due to the shifts in season, the resting time between the two growing seasons has been reduced from three months to two months. The communities also reported an increasing number of storms with wind and rain, which are causing significant damage to the villages hit.

Farmers have started to adapt to these changes by cultivating bigger areas to compensate for lower yields, sowing earlier to ensure catching the first rains, growing more second-season crops (such as beans, cotton and sesame), increasing cultivation in the low-lying areas and planting more drought-resistant crops (such as banana, sweet potatoes and cassava). The participants are aware of and agreed that there are other solutions, such as improved seeds, conservation farming and mechanisation and irrigation, but stressed that improved access to clean water is their number-one priority and concern.

"Win-win options" refers to the difference between doing "business as usual" and being "sustainable in the long term". They require the promotion and facilitation of investment by responsible companies willing and able to pay for adaptation and conservation to curb the depletion of natural resources due to human action and climate change. They also require recognition of the fact that nature must be protected as a system and that resources with economic value and resources with no economic value must function together.

Government has an important role to play in investors switching from the concept of "business as usual" to that of "sustainable in the long term". It should encourage investors with plans already approved and/or land in the area already allocated to implement adaptation by:

(i) supporting the introduction of green technology through the funding of the difference in the cost of the installation of standard technology and that of improved, energy-efficient technology; and

(ii) identifying suitable and available land for investment and proactively inviting a selection of corporate-responsible investors to act as role models to others in the sector.

Four responsible companies and consortia with real investments in the pilot geographical area in Cabo Delgado Province were consequently identified. They can, due to the scale of their operations and of the resources provided by them, afford to pay for adaptation measures in the pilot geographical area. For them to invest in adaptation measures, however, awareness needs to be created and the climate of investment and of doing business in the country needs to be favourable.

From recent studies, it is clear that Mozambique's business environment remains constrained. While there is a long list of concerns and barriers reported by companies doing business in Mozambique, the top five concerns seem to be related to governance, crime, access to finance, tax and infrastructure. How serious these barriers are perceived to be very much depends on the sector and the location of investment. The top five positive and top five negative factors differ from province to province.

Figure 48 shows the main negative and positive factors both for the national level and for Cabo Delgado Province.

Specific positive and negative factors both for the national level and for Cabo Delgado Province		
Top five negative factors		
	National level	Cabo Delgado
1	Illegal imports	Bureaucracy
2	HIV/AIDS, malaria and other diseases	Crime level (personnel safety)
3	Crime level (personnel safety)	Roads
4	Organised crime	Corruption
5	Corruption	HIV/AIDS, malaria and other diseases
Top five positive factors		
	National level	Cabo Delgado
1	Postal and communication services	Electricity and water supply
2	Electricity and water supply	Contract enforcement
3	Contract enforcement	Trade union activity
4	Business start-up regulations	Business start-up regulations
5	Market demand	Postal and communication services
KPMG, Business Confidence Index, June 2009		

Figure 48: Results of the KPMG business-confidence index survey of 938 companies conducted during the last quarter of 2008 and the first quarter of 2009

The results of the above-mentioned survey show an increase of 7.08% in the business-confidence index. The 2010 KPMG report lists similar positive and negative factors but also shows tax as one of the top negative factors but market demand and air transport as positive factors for Cabo Delgado. The 2010 business-confidence index, at 101.5, shows a decline of 4.34% compared with 2009 figures. Cabo Delgado ranks sixth, with a business-confidence index of 101.26%.

Setting up a business involving land can take as long as five years. The delays associated with overcoming the many barriers involved in obtaining the required registrations, licences, negotiations, applications and approvals not only frustrate private investors, who may lose interest and decide not to invest, but also affects local authorities and communities, who perceive the delays as broken promises and then lose confidence in the investors.

The costs of "using" the environment and natural resources are higher for those who decide to take on adaptation and the responsibility for costs that have often, to date, been considered as externalities. Private-sector investment in adaptation measures beyond corporate social responsibility involves long-term, proactive engagement and will take place only if the overall economic environment is attractive.

A second study looked at how to engage the private sector to implement adaptation measures with high levels of investment and impact at national level. Whereas the previous section describes a bottom-up approach to identify sustainable investment opportunities (involving land) while simultaneously building resilience in surrounding communities, this section outlines a more top-down approach, which starts by identifying the greatest risks faced by the country and then logically identifies major interventions to reduce vulnerability.

One important factor should be noted in respect of this top-down approach and that is that it aims fundamentally at involving the private sector beyond the concept of corporate social responsibility. Projected financial returns and business risk mitigation are therefore key considerations in the selection of projects. Many projects that would significantly improve infrastructure, and flooding impact and water stress resulting from climate change could be identified. Investment in these projects, however, would likely arise only from donor or government money, as they have little potential to generate a financial return or to make sense for a business to invest in given tangible risk reduction to business continuity.

This study therefore put forward those projects and programmes that would have a high impact on climate resilience and that would have high relevance for the private sector, thus providing a meaningful and realistic opportunity for third-party private-sector investment. This would optimise the probability of the programmes' pilot projects being rolled out and scaled up with far greater effect while simultaneously minimising ongoing donor support.

It should also be noted that adaptation and mitigation are related at different levels of decision-making[32] and are therefore often combined in the selected private-sector portfolios. The selected options generate profitable business and important capacity-building in climate change priority areas. They will increase the resilience of the population in dealing with climate shock through risk reduction, awareness creation, improved (more resilient) infrastructure, poverty reduction and the diversification of income through employment opportunities and other supply-chain impacts.

[32] IPCC AR4 WG II report, 2007, chapter 18. Mitigation efforts can foster adaptive capacity if they eliminate market failures and distortions as well as subsidies that prevent actors from making decisions on the basis of the true social costs of the available options. Mitigation reduces all impacts (both positive and negative) of climate change and thus reduces the adaptation challenge. Adaptation strategies, such as afforestation, also make a positive contribution to mitigation.

Figures 49 to 51 summarise the approach followed to arrive at the final short-list of priority projects.

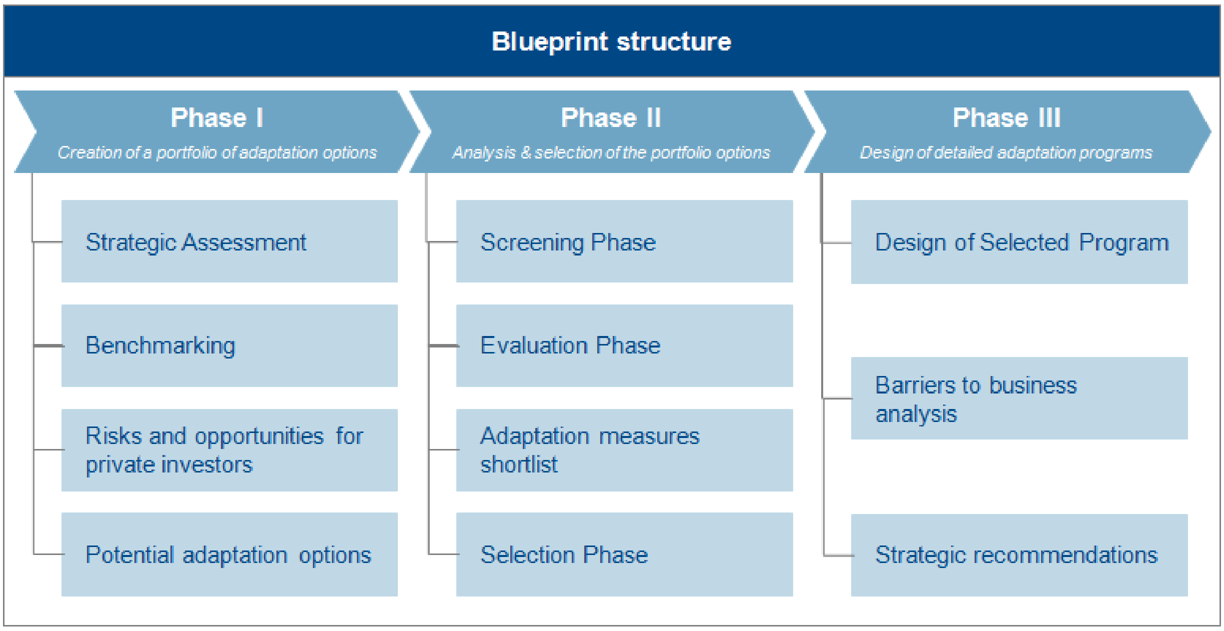


Figure 49: Approach taken to identify commercially viable adaptation measures

As can be seen from Figure 49, during INGC Phase I, strategic objectives were formulated, successful projects worldwide were identified to generate ideas through global benchmarking, climate change and other risks and opportunities per geographical area in Mozambique were summarised, and a long list of potential adaptation options was established.

During Phase II, the long list was subjected to a series of criteria in the screening phase, which generated a reduced list. This underwent high-level cost-benefit and feasibility analysis in the evaluation phase to generate a short-list. The selection phase of choosing the final programmes to start private-sector engagement consisted of site visits, an analysis of financing options and private-sector consultations.

Phase III consisted of the detailed design and budgeting of the selected programme, an analysis of specific barriers to the programme and recommendations to address these to make implementation a success.

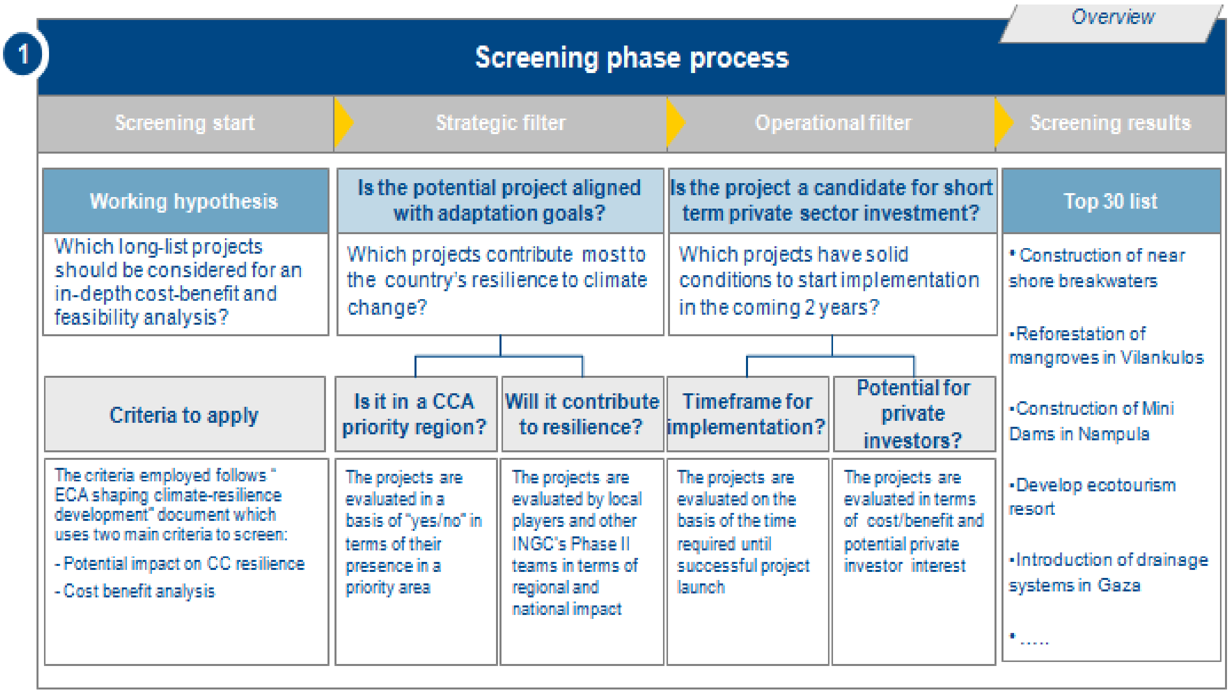


Figure 50: The screening phase, which brought the long list of 75 measures down to a reduced list of 33 measures

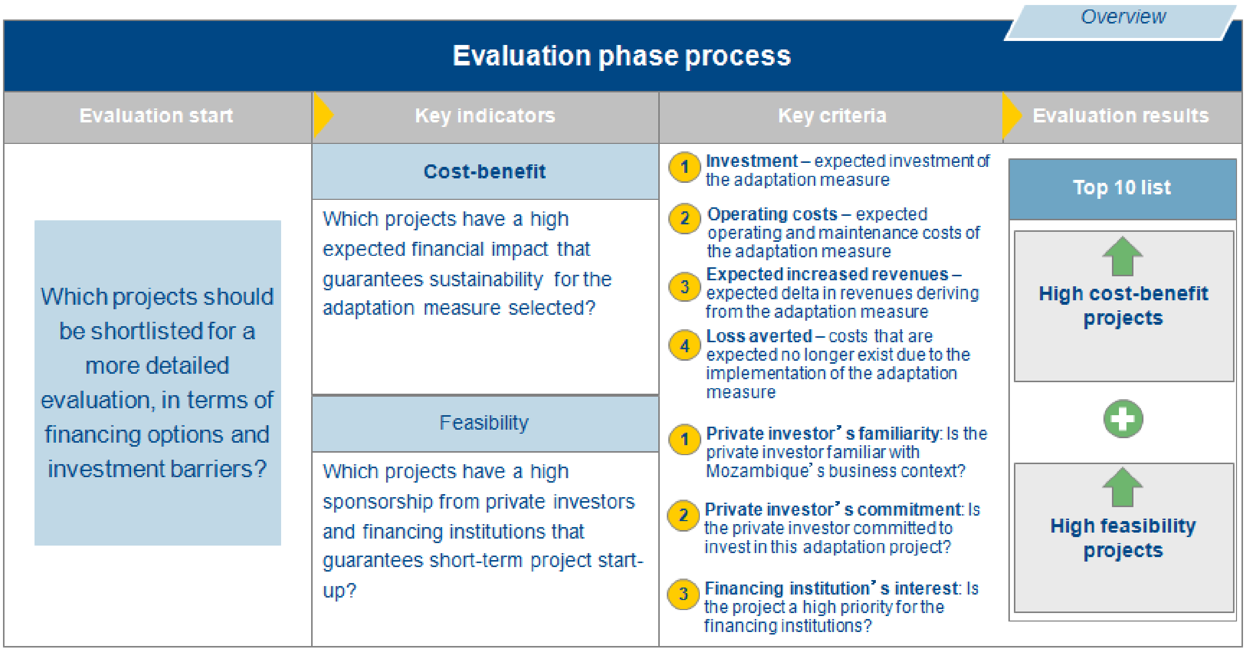


Figure 51: The evaluation phase, which brought the reduced list of 33 measures down to a final short-list of 12 measures

A scoring system was applied to select the measures with the highest score (0.7 or higher) for the key criteria shown in Figure 51. Cost-benefit estimation was based on existing private-sector documentation, other INGC Phase II thematic work (such as coastal protection) and detailed case studies in other countries. The feasibility analysis was based on consultations with private investors, private financial institutions and international sources of development financing.

The following section (Figures 52 to 57) outlines some of the key results of the blueprint process followed, starting with an overview of the Mozambican business context (a strategic analysis) to identify high-risk, high-impact areas, the final short-list and the selected programme, barriers to investment and strategic recommendations to facilitate implementation.

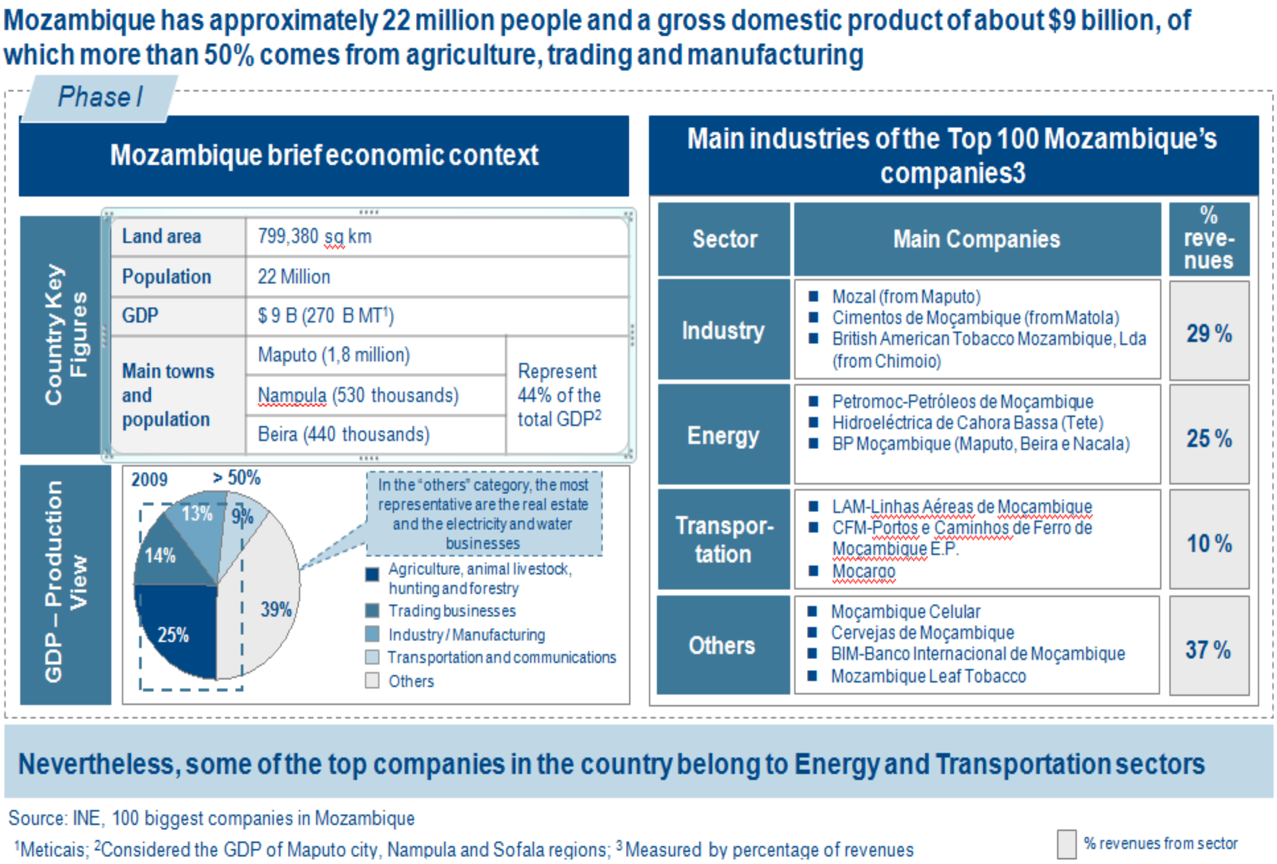
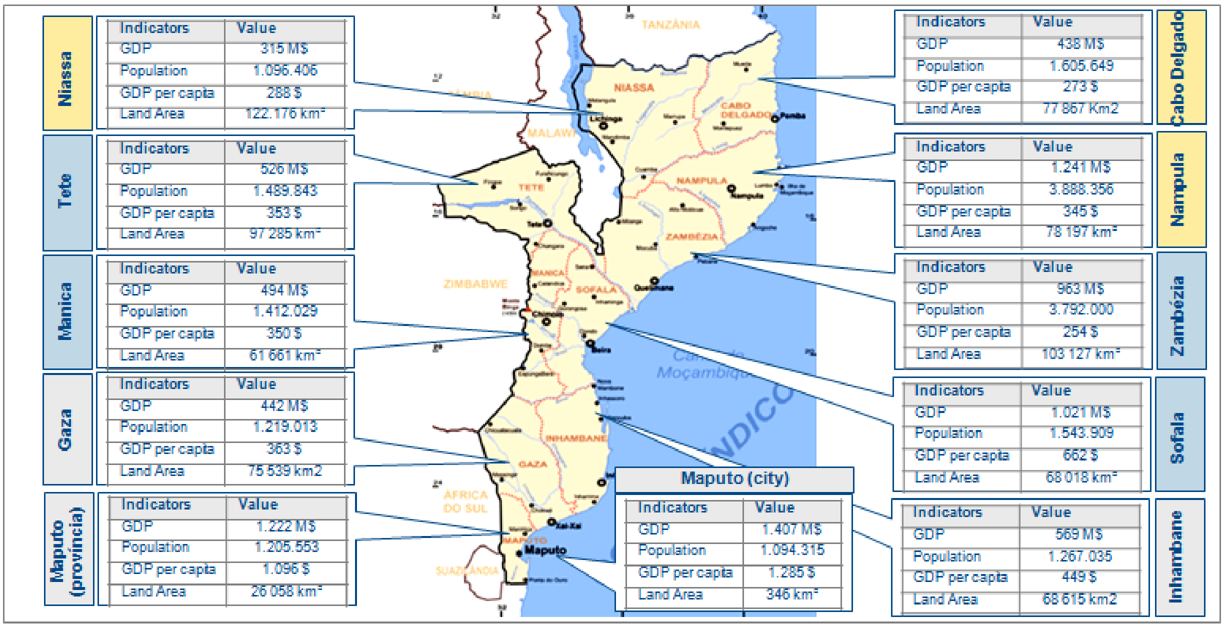


Figure 52 A: Mozambican economic context: Key figures and main industries

In more detail, the provinces that have the higher percentage of country's GDP are Maputo city and province, Nampula and Sofala



Niassa

Indicators	Value
GDP	315 M$
Population	1.096.406
GDP per capita	288 $
Land Area	122.176 km²

Tete

Indicators	Value
GDP	526 M$
Population	1.489.843
GDP per capita	353 $
Land Area	97 285 km²

Manica

Indicators	Value
GDP	494 M$
Population	1.412.029
GDP per capita	350 $
Land Area	61 661 km²

Gaza

Indicators	Value
GDP	442 M$
Population	1.219.013
GDP per capita	363 $
Land Area	75 539 km2

Maputo (provincia)

Indicators	Value
GDP	1.222 M$
Population	1.205.553
GDP per capita	1.096 $
Land Area	26 058 km²

Maputo (city)

Indicators	Value
GDP	1.407 M$
Population	1.094.315
GDP per capita	1.285 $
Land Area	346 km²

Cabo Delgado

Indicators	Value
GDP	438 M$
Population	1.605.649
GDP per capita	273 $
Land Area	77 867 Km2

Nampula

Indicators	Value
GDP	1.241 M$
Population	3.888.356
GDP per capita	345 $
Land Area	78 197 km²

Zambézia

Indicators	Value
GDP	963 M$
Population	3.792.000
GDP per capita	254 $
Land Area	103 127 km²

Sofala

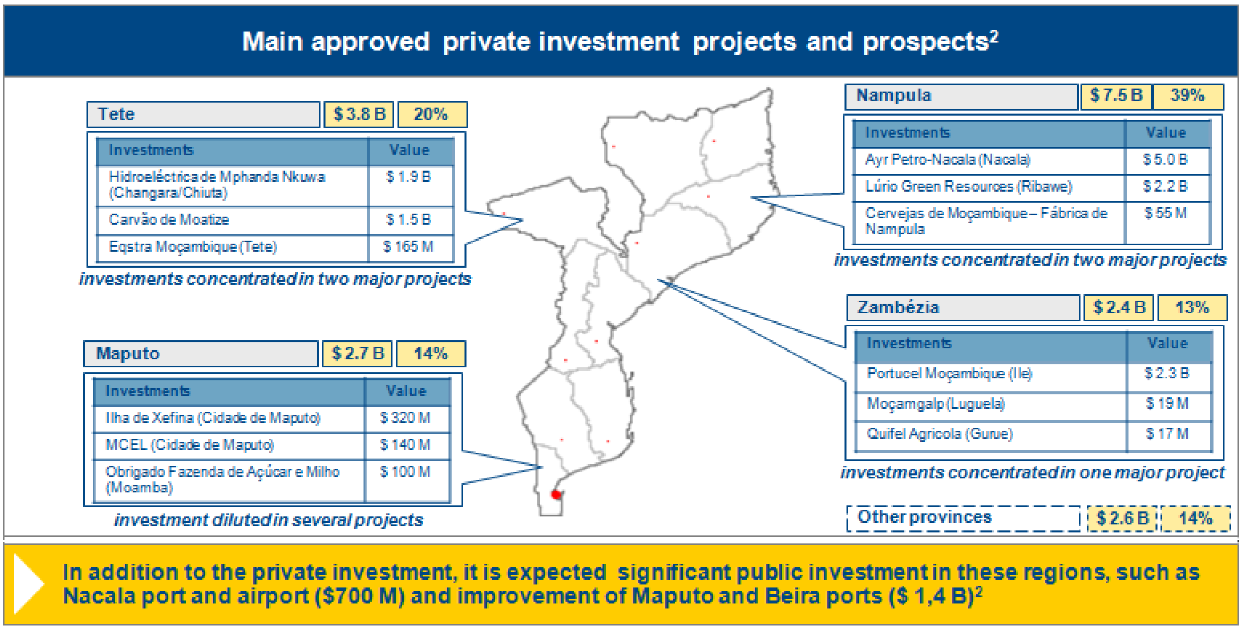
Indicators	Value
GDP	1.021 M$
Population	1.543.909
GDP per capita	662 $
Land Area	68 018 km²

Inhambane

Indicators	Value
GDP	569 M$
Population	1.267.035
GDP per capita	449 $
Land Area	68 615 km2

Figure 52 B: Mozambican economic context: Provincial population, GDP and land area

The value of approved investments that will take place in the short to medium term[1] is worth some $19 B, of which more than 80% are located in Nampula, Tete, Maputo e Zambézia



Main approved private investment projects and prospects[2]

Tete | $ 3.8 B | 20%

Investments	Value
Hidroeléctrica de Mphanda Nkuwa (Changara/Chiuta)	$ 1.9 B
Carvão de Moatize	$ 1.5 B
Eqstra Moçambique (Tete)	$ 165 M

investments concentrated in two major projects

Maputo | $ 2.7 B | 14%

Investments	Value
Ilha de Xefina (Cidade de Maputo)	$ 320 M
MCEL (Cidade de Maputo)	$ 140 M
Obrigado Fazenda de Açúcar e Milho (Moamba)	$ 100 M

investment diluted in several projects

Nampula | $ 7.5 B | 39%

Investments	Value
Ayr Petro-Nacala (Nacala)	$ 5.0 B
Lúrio Green Resources (Ribawe)	$ 2.2 B
Cervejas de Moçambique – Fábrica de Nampula	$ 55 M

investments concentrated in two major projects

Zambézia | $ 2.4 B | 13%

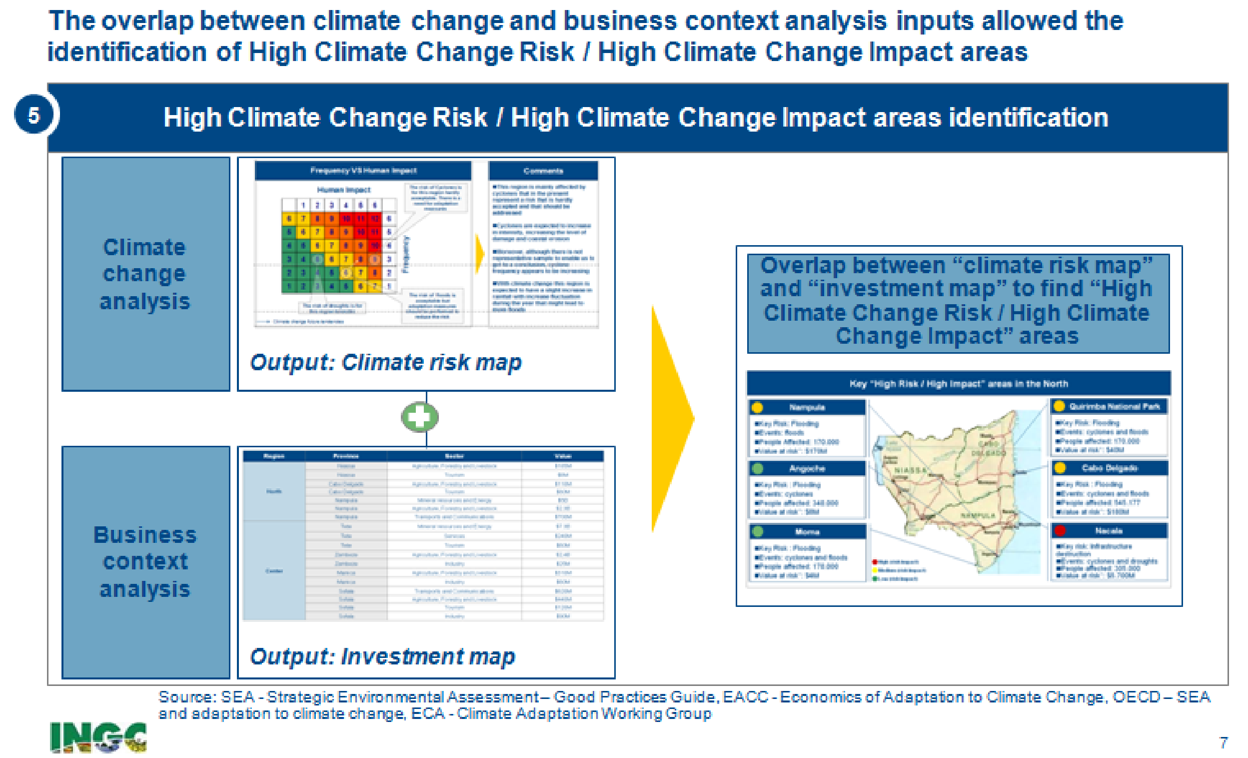
Investments	Value
Portucel Moçambique (Ile)	$ 2.3 B
Moçamgalp (Luguela)	$ 19 M
Quifel Agricola (Gurue)	$ 17 M

investments concentrated in one major project

Other provinces | $ 2.6 B | 14%

In addition to the private investment, it is expected significant public investment in these regions, such as Nacala port and airport ($700 M) and improvement of Maputo and Beira ports ($ 1,4 B)[2]

Figure 52 C: Mozambican economic context: Major investments



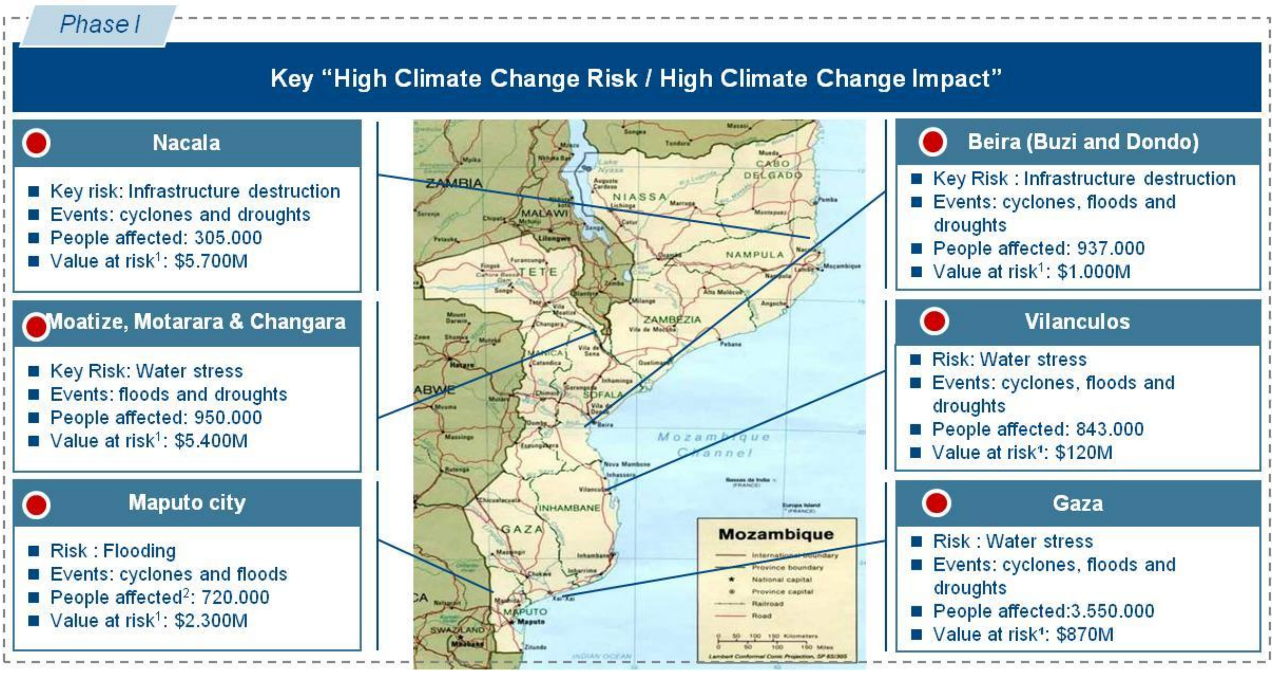


Figure 53 A and B:Identification of high-risk, high-impact areas from the private-sector perspective

The overlap between the climate risk map and the investment map (A) indicates six priority areas of high climate change risk and high climate change impact (B), with an estimated value at risk in the order of US$14 billion and a population of approximately seven million people. The The main INGC Phase II report also shows the medium and low-risk areas and explains the methodology applied.

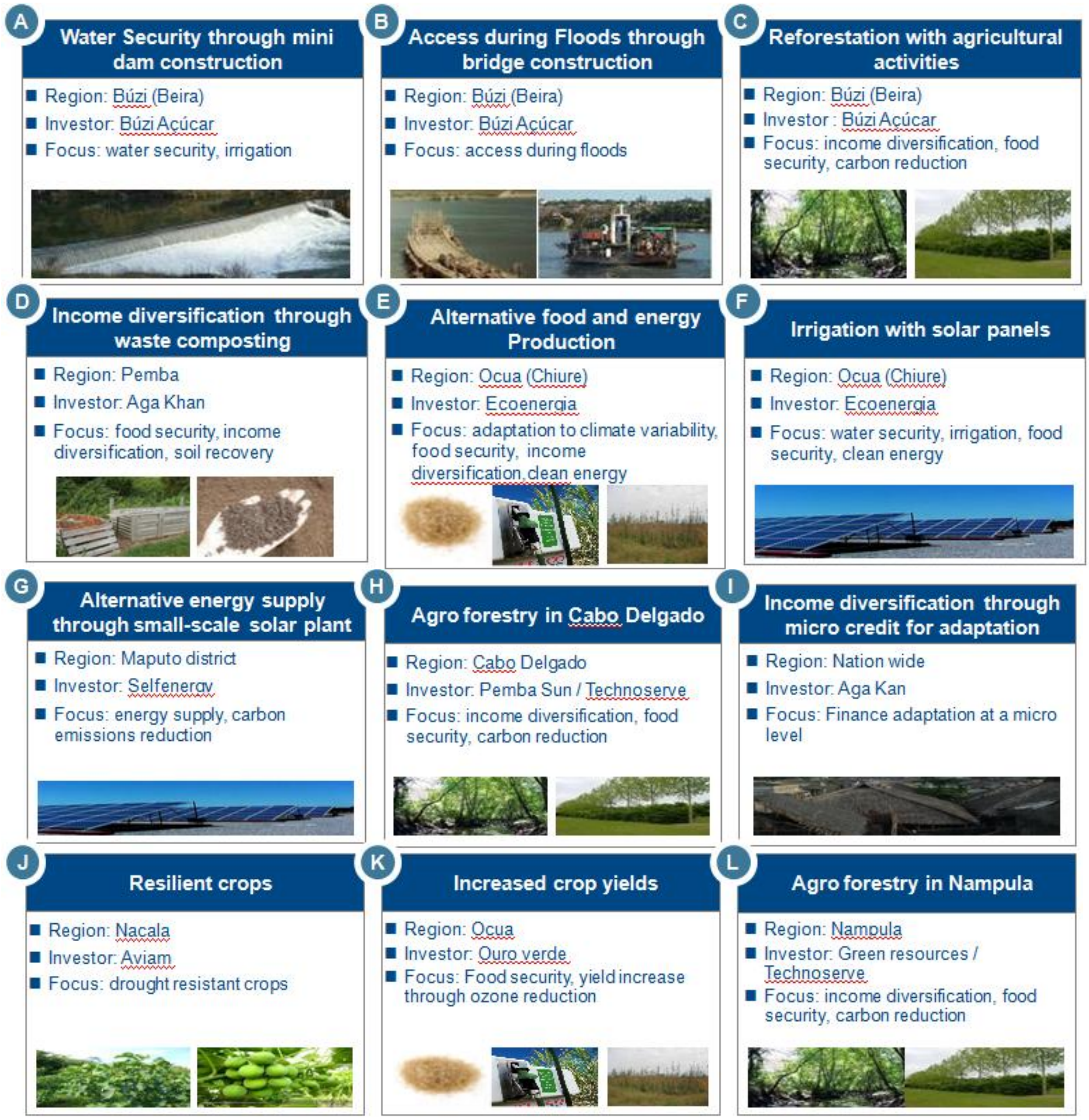


Figure 54: Establishment of the short-list of 12 adaptation opportunities through strategic country analysis, benchmarking, the identification of high-risk, high-impact areas, screening and evaluation

Figure 55 shows the short-listed measures organised by sector.

Project aggregation by strategic area				
Projects / Areas	Energy	Water	Tourism	Forestry/ Agriculture
Alternative food and (renewable) energy production, CD	X	X		X
Increase crop yields, nationwide				X
Reforestation with agricultural activities, Buzi				X
Development of agro forestry, CD, Nampula				X
Income diversification with waste composting, nationwide	X			X
Irrigation with solar panels, Gaza, CD	X	X		
Resilient crops, Nacala, Gaza		X		
Water security and energy with Mini Dams in Búzi River	X	X	X	
Small Scale Solar Plant, Maputo	X		X	
Access during floods through bridge construction, Buzi		X		
Income diversification through microcredit for adaptation, nationwide	X		X	
Identification of new programs e.g. insurance, company early warning systems, other	X	X	X	X

Figure 55: Short-listed measures aggregated into sectorial programmes

A fifth stream of activities would consist of the continued identification of new measures, as the cut-off for the four programmes was dictated by time and budget and not by lack of opportunity.

Although all five programmes are considered effective private-sector opportunities, only one could be worked out to implementation level in the timeframe available. The selection of the first programme for private-sector investment was based on a ranking of investment barriers and on the potential impact on communities in terms of building resilience to climate change. The overarching theme of a community energy programme was selected as the best first candidate for both vulnerability reduction and attracting interest from the private sector. The water programme, for example, while highly relevant to community resilience, shows more difficulty in generating attractive returns on investment. Adaptation measures in the water sector should nevertheless entail tangible benefits for existing companies depending on a reliable water supply for their business and an in-depth cost-benefit analysis at corporate level on water adaptation, early warning and community resilience is planned for 2013.

The implementation of the three remaining programmes and the exploration of subsequent programmes will depend on the successful start of the first programme and on the start-up capital.

Community Energy Program – Summary of Activities

Implement pilot projects and gather new investors for the Programs' roll-out to a portfolio of projects. Portfolio building, monitoring pilots and feedback cycle to ensure lessons learned are incorporated into following projects.

Clean Energy

Micro (1-10 kW), Mini (10-100 kW), Distributed Utilities (100-1000 kW) projects

Pilot: 1 MW PV plant in Maputo

Capacity building

Personnel with capacity to understand the specificities of the project and negotiate with the Government and funders. Personnel with fund raising capacities . Personnel with deep knowledge of renewable energy (solar, wind, hydro), CDM and other financing mechanisms and of the Mozambican reality

Types of funders

Specialized funds, Private Equity, National & Multilateral Development Finance, Industry

Duration /Cost Pilot: 12 months/$ 375,000 (total private investment $4.5 million)

Forecasted private sector investment, 5 years: approx. USD 250 million for 33 MW

Benefits: 575,000 people and hundreds of businesses with electricity access. Improved productivity, improved living conditions, improved health facilities, reduced pollution, easier access to early warning through improved connectivity

Major challenges

Negotiating with FUNAE, EDM or other Government institutions. All the installation operational issues. No defined feed-in tariff system, lack of financial capacity, very disperse locations, bureaucratic licensing process,

Composting

Solid organic waste treatment for agricultural fertilizer production

Pilot: Pemba

Capacity building

Personnel with capacity to understand the specificities of the project and negotiate with the suppliers, funders and end consumers. Personnel with fund raising capacities

Types of funders

Environmental Funds, Private Impact, Grants & Foundations, National & Multilateral Development Finance

Duration/Cost Pilot: 12 months/$180,000 (total private investment $400,000)

Forecasted private sector investment, 5 years: approx. USD 20 million

Benefits: Pilot: aprx 100,000 people, reduction in contamination of soil, groundwater, air (CH4, CO2), 95 tons of fertilizer for yield increase from the pilot (Year 1), income generation

Major challenges

Optimize the waste collection and the fertilizer production with the consumption/sales. Guarantee buyers for the fertilizer. Seasonality and variance in conditions. Relatively high operating / maintenance costs. Lack of incentives for composting. Requires presence of basic utilities. Educating populations on correct waste separation and the benefits of compost in agriculture. Creating effective network of waste collectors and fertilizer distributors

Micro & Small Scale Lending

Class A loans ($100-5000), Class B loans ($10,000-$100,000). Access to water, irrigation, mangroves, house refurbishment

Pilot: Maputo and surrounding area

Capacity building

Personnel with experience in setting up a financial institution, financial and accounting knowledge, and capacity to negotiate with the funders and MFIs. Personnel with fund raising capacities

Types of funders

Regional and international wholesale banks, National & Multilateral Development Finance Institutions, Micro-Finance Funds

Duration/Cost Pilot: 12 months/ $ 365000 (total private investment $2.5 million)

Forecasted private sector (bank) investment, 5 years: approx. USD 25 million

Benefits: Financial inclusion. Pilot: Aprx. 190 projects , 1 year. Improved resilience to climate change shocks (agriculture, water, housing)

Major challenges

Negotiating with the partners and investors. Quality of governance. Track record of counterpart. Transmit confidence to borrowers. Ensure an adequate balance of interests, management costs and borrowers capacity to pay. Educate populations for this type of lending. Evaluate project impact in building resilience for climate change. Network reach that covers all target populations

Figure 56: Selection of the community energy programme as the best first candidate for vulnerability reduction and attracting interest from the private sector

A pilot phase is planned for each work stream within the programme, as shown here in Figure 56 for three of the programmes.

The clean energy programme will build resilience to climate change through the concept of distributed power generation based on micro and mini-power generation from renewable sources of energy, thus developing the off-grid electrification of Mozambique, which is so important at all levels of socio-economic development. This will also increase chances that hospitals, schools and mobile stations can continue to function in the event of disaster or power failure.

The composting programme will promote significant volumes of the production of organic fertiliser from waste, thus encouraging the development of a fertiliser-based agriculture (which has been decreasing in Mozambique for the last few years) and contributing to a significant improvement in crop yield and reduced run-off and soil erosion. When applied in cities, this programme will also have important waste and health-risk reduction impacts on, for example, groundwater and air contamination.

The small-scale lending programme will facilitate the provision of loans for sustainable development and adaptation to climate change in both urban and rural settings.

Private-sector partners were identified for these programmes or work streams if public funding can be mobilised to help fund the pilot projects. The detailed programme proposals are contained in the main INGC Phase II report.

A Program set up

- Identify all the core competences needed for each Program and start a Human Resources work thread by identifying suitable candidates and giving them the proper training
- Define the articulations of each Program with the Governmental institutions to maximize the existing structures, optimize the relationships and avoid any clashes
- Identify all the suitable partners and investors and start building-up & formalizing the relationship with them
- Secure the necessary funding for the capacity building phase
- Finalize the identification of the pilot projects, identify all the investments necessary and define the timings for their implementation

B Pilot Projects' set up and implementation

- Start gathering the teams for each pilot project (composed of external experts and local resources)
- Put each pilot project in place, and build necessary relationships with end-users and consumers
- Build institutional support at the national, regional and local levels
- Create awareness for the pilot projects – and their climate adaptation benefits - at both the national and international level
- Secure funding for the pilot projects and organize roadmap and road shows for funding the building of the pipeline of projects to make up the Program portfolio

C Pipeline of projects

- Intensify the road show presentations and fund raising activities to maximize the number of projects in the portfolio of each Program
- Populate each Program portfolio with new projects
- Market these projects/Programs to the international community
- Increase the involvement of the local teams and resources to start the "capabilities transition process"
- Invite researchers and investigators to participate in the Programs and support them in publishing the results of their observations
- Implement the monitoring systems for measuring climate adaptation benefits and sustainability of the projects

Figure 57: Community energy programme: The three start-up phases: An initial set-up phase; the pilot project set up and implementation; and a comprehensive pipeline of follow-on projects

The organisational structure of the selected programmes should be characterised by the highest level of political leadership and a clear and swift strategy approval process, characterised by a unique point of contact, as illustrated in Figure 58.

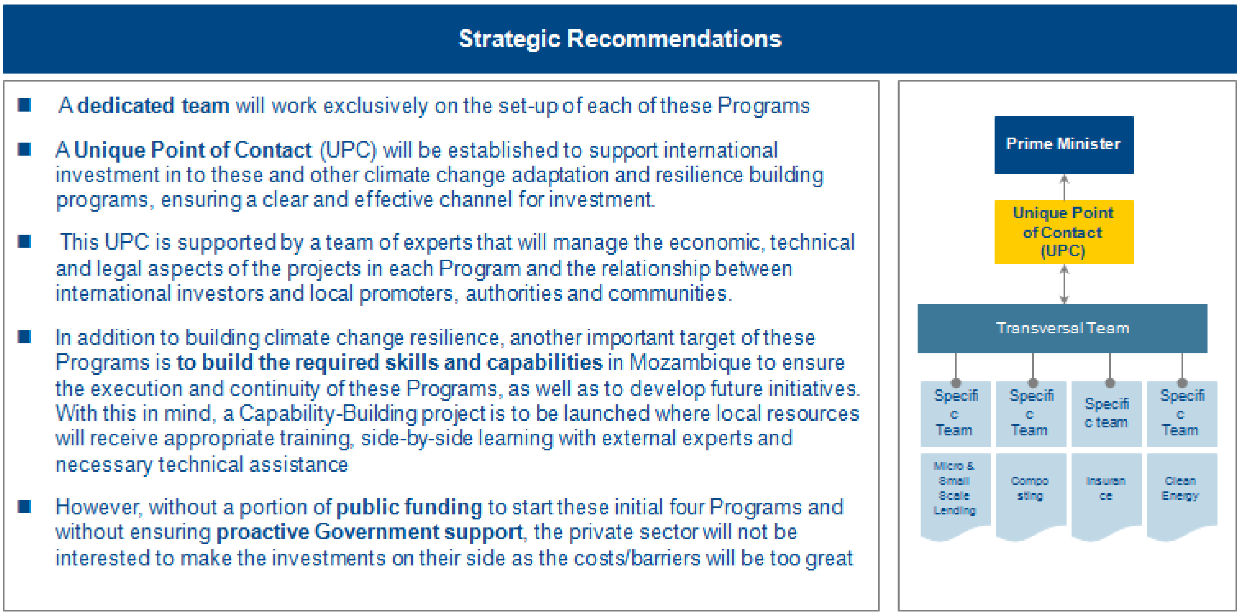


Figure 58: Community energy and the three subsequent private-sector programmes: Organisational set up

Figure 58 illustrates the organisational set up of the community energy and three subsequent private-sector programmes characterised by a unique point of contact. This point of contact would have the capacity to deal directly with international investors (impact investment funds, banks and others). It would also have a deep knowledge of the Mozambican reality and government structures, it would ensure coordination between the international investors and all the entities involved in the approving, licensing and monitoring of the programmes and it would scout for new projects and programmes.

The transversal team would define the global strategy for the programmes and the operational model, the road-map and the capacity-building requirements, it would help to fundraise and monitor the projects' sustainability and it would evaluate new projects and programmes.

The specific teams would have specific competencies for each programme (technical, legal, administrative and logistical) and they would be responsible for the direct operational management of the projects within each programme and for the delivery of the necessary training to foster autonomy.

Insurance

An important and complementary issue is the functioning of a robust insurance sector in helping to make projects investable for the private sector and financiers. How can the involvement of the insurance sector have a positive impact on climate resilience within the four programmes now and into the future? A significant number of major global insurance and reinsurance companies (including AXA, Allianz, Swiss Re, Micro-ensure, Zurich, the Willis Group, Hartford, Fin-mark, CDC, Bankable Frontiers, Nedbank, Guy Carpenter, Climate Wise and Micro-risk) were interviewed and their views sought on their potential deeper involvement in the programmes into 2012 and beyond.

Box 8: Insurability of adaptation programmes: Points raised by insurance companies

- No major insurance player has a real presence in Mozambique. The opportunity in Mozambique for insurance companies compared with the lack of understanding and uncertainty makes working in the country a difficult proposition. A stable regulatory framework and strong governance are needed if a higher penetration of products is to develop:

  Why would my Board sanction spending significant time and effort on product R&D in such a challenging environment when the margins are likely to be so low and country, security and regulatory risks are so high?
  Head of Climate Risk, global insurance/reinsurance firm

- Insurance is not a silver bullet to managing climate change but understanding the way in which insurance products are priced would encourage prudent risk management. This would also result in more insurable risks at the end of the day.
- Insurance products come at the end of a risk management process. Addressing project-level risk in a prudent, methodological way is a vital step towards creating an environment in which appropriately priced insurance products can be delivered. Each programme would therefore be subject to robust loss-and-damage methodology.
- It is often cheaper to address risk rather than insure it. Each programme would therefore have to determine the extent to which expected loss under a high climate change scenario could be cost-effectively averted through prevention and intervention measures. The availability and accessibility of emergency services and disaster intervention could also play a part in mitigating project risk. The residual risk could then potentially qualify for insurance.
- Insurance companies place a good deal of emphasis on construction quality, since this greatly affects the likely value at risk. Insurance companies working closely with the building industry and introducing relevant and reliable building and planning standards that take identified climate adaptation risks into account could therefore have a significant impact in lower indemnity insurance premiums.
- A major issue that needs to be addressed when climate and weather-related issues are insured through indemnity-type insurance is overcoming significant cluster risks. Flooding, SLR and drought would cause a large concentration of insured parties to claim. Programmes that focus entirely on mitigating disaster and weather-related risks would be highly subject to cluster risks and would be challenging for insurance companies to price correctly.
- It is much easier for the insurance sector to become involved in the insurance of products, components and equipment rather than of weather, events or climatic conditions. Elements of both exist in all four proposed private-sector programmes:

  Risks that are product-related must be distinguished from those that are weather-, climate- or event related. If construction of infrastructure or the installation of equipment is part of the *programs, it is vital that these take into account extreme conditions. Re-insurance can then attempt to cover disaster scenarios.*

Swiss Re, climate risk

- A major stakeholder awareness and education programme would have to be conducted to build trust in the role of insurance in building climate resilience into the private sector. There is a real lack of understanding about insurance products in the developing world ("Why would I pay for something that I might never see the benefit of?"). Insured parties also need to trust that they would, in fact, be paid out. A pilot project could be used to increase awareness of appropriate climate risk management requiring a balanced portfolio of prevention, intervention and insurance measures.
- The presence of a specific work stream on data mapping would be vital to creating greater confidence in the value at risk of the four programmes. The availability of reliable, historical data remains a critical factor in determining risk to insurers in respect of indemnity insurance. High-resolution data are, however, less relevant in respect of index-linked or parametric insurance. The latter could therefore provide a more appropriate method of tackling weather and event-related risks, given the far lower actuarial burden on the insurance firm.

In view of the above, it seems unlikely that international insurance companies would have the appetite for significant involvement in the insurance of these types of products (such as the four programmes identified) in the near future. A local insurance market with a supporting legal framework is certainly required. Progressive parts of the international reinsurance sector would be more likely to have an appetite for involvement if the scale were large enough. Interviewees did feel that the programme being endorsed and driven by the Government of Mozambique would have a strong element of drawing together relevant parties. A pilot project approach that is action-oriented and that has already attracted financing interest would also increase the likelihood of results in the next phase. There is interest from identified partners to use the pilot programme approach to refine the pricing and risk evaluation of insurance products. Such an assessment, along with a distribution and collection analysis and a data-mapping exercise, would be logical next steps.

Barriers

Interviews with potential investors revealed a strong sentiment that doing business in Mozambique is difficult and cumbersome and that this perception (or reality) would be one of the key barriers to overcome if the gates to significant private-sector funding for climate change adaptation measures were to be fully opened up.

Without a portion of public funding to undertake the pilot projects of the first programme (Figure 56) and without proactive government support, the private sector would not be interested in making the required investments from its side, as the costs and barriers would be too great. Such public or government support could include technical assistance or studies, or the funding of capacity-building for the development of the necessary local skilled workers, professionals and project managers who would be required to support and oversee the implementation of the programmes.

Securing funding for the programmes (both the pilots and the pipeline projects) would require a concerted effort in working with investors, the unique point of contact, the transversal team, the specific teams and the network of authorities, local partners and businesses, and communities.

Investors evidenced the following as critical factors in their investment decisions: the existence of a solid track record; high returns to compensate for the risk; the existence of trust and trustable persons; a strong working knowledge; and quality of governance. These are factors not easily achieved. Investment barriers, such as country risk, regulatory risk and corruption, all reduce the appetite of investors and increase the returns that they demand for investment in a country.

Potential investors are furthermore reducing their actual lending as a result of the global financial crisis. Other factors at play here are the significant drop in prices paid for carbon credits under the European Union's emission-trading scheme, the additional eligibility restrictions planned for 2013, the tremendous system delays in certification and validation and the termination of the investment periods of some of the large, early funds designed to support emission-reduction projects[33].

Despite lowered investment appetite, creating a relationship in the short term with potential investors in public and private (micro-finance and private equity) financial institutions is important, as it will take time to convince these investors that the proposed projects are worthy of their currently scarce capital[34].

The involvement of relevant authorities and experts knowledgeable about the Mozambican reality at an early stage is key to the reduction of barriers. Early discussions with local and regional governments would identify the level of support that they would provide the different projects and how their own efforts would fit with those of the private sector. Discussions would also prime them to discussing future legislation with investors and developers. The developers of local, comparable projects could provide their experience and identify the major challenges that they have faced and those (related to supply chains, the access of foreign finance and local government regulations) that they would forecast as project numbers increased.

4.6 OCEAN CLIMATE CHANGE AND THE IMPACT ON FISHERIES (A START)

With such a long coastline and economically important fisheries, it is of interest to look in more detail at what is happening in the Mozambique Channel and surrounding Indian Ocean. How would the present-day ocean climatology of the south-western Indian Ocean change due to global warming and what could the implications for the oceanographic climatology and fisheries in the Mozambique Channel be?

It is important to note that global ocean heating occurs at a much slower pace than heating trends evidenced on land. The world's ocean was responsible for absorbing approximately 84% of the total increase in the heat content of the earth's system from 1955 to 1998 (for 43 years), which corresponded to a mean temperature increase of 0.037 ^{o}C (Levitus *et al*., 2005). Models show heating trends in the upper 800 m of approximately 0.5 ^{o}C in 200 years.

However, while the mean SLR all around the global ocean is related to a gradual rise in global temperature and the melting of polar ice-caps, other factors that influence SLR are also at play, as explained in Box 9 below. It is important to note that great uncertainties still exist about climate change science and that the current drive is to decrease these uncertainties. Society cannot, however, wait for 100% certainty before reacting.

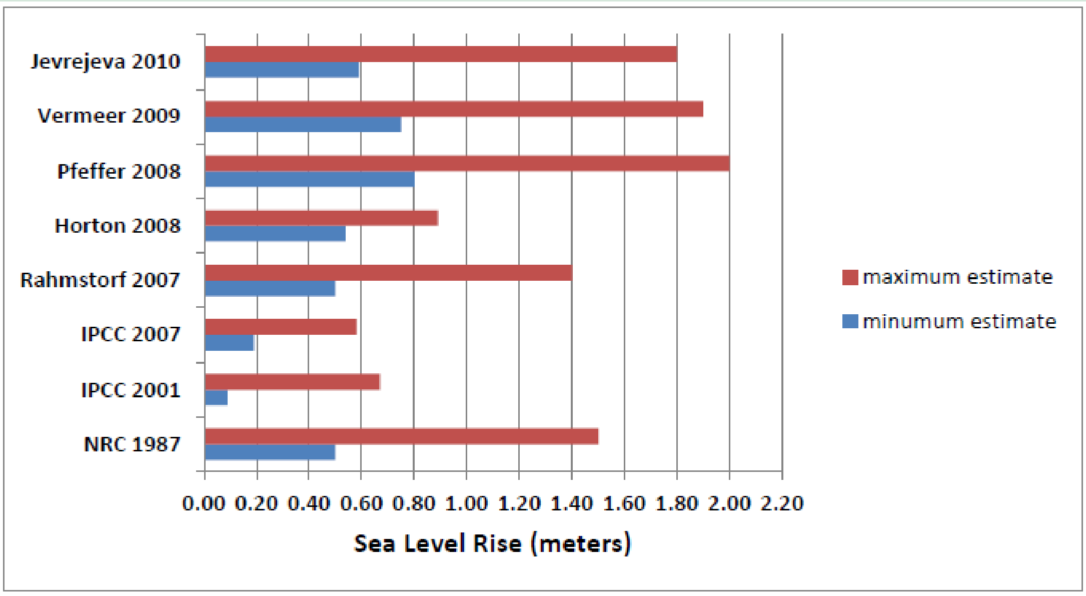
[33] Comment from the DAI/SPEED programme.
[34] ibid

Box 9: SLR

Global average eustatic or absolute SLR results mainly from a combination of an increase in ocean volume due to lower sea-water density arising from a warmer ocean temperature and lower salinity and of an increase in ocean mass due to a redistribution of fresh-water from land-based storage (such as glaciers, ice sheets, dams, lakes, rivers and ground-water) to the oceans (Ministry for the Environment, South Africa, 2008). Sea level therefore rises when melt-water from land-based masses of ice, such as glaciers, flows into the ocean but sea level also rises when heat from the atmosphere is mixed into the upper layers of the ocean, causing that water to expand. In recent decades, this thermal expansion has provided, on average, only about one-quarter of the SLR seen each year but its contribution is increasing (Gillett *et al.*, 2011). Researchers now, however, point to an even bigger threat from warm ocean waters and that is that the floating ice shelves that ring Antarctica could melt, as could the seaward end of land-based ice streams, which would lead to a long-term, catastrophic rise in sea level (Gillett *et al.*, 2011). In combination with other factors, like subsidence and glacial isostatic adjustment, SLR relative to the land will be highly localised (PIANC, 2008). At mid-latitudes, the mean SLR will be generally higher than in the equatorial area (IPCC, 2007) due to changes in ocean density distribution (steric SLR).

Recent observations from satellites, very carefully calibrated, reveal a global SLR over the last decade of 3.3 +/- 0.4 mm/y (Rahmstorf *et al.*, 2007). The IPCC AR4 report (IPCC, 2007) concludes that anthropogenic warming and SLR would continue for centuries because of the time scales associated with climate processes and feedbacks even if greenhouse gas concentrations were stabilised. Comparisons between about 30 years of South African tide gauge records and longer-term records elsewhere show substantial agreement. A recent analysis of sea water levels recorded at Durban confirms that the local rate of SLR falls within the range of global trends (Mather, 2008). Present South African SLR rates for the east coast are +2.74 mm.yr-1 (Mather *et al.*, 2009).

The probability of sudden large rises in sea level (possibly by several metres) due to a catastrophic failure of large ice shelves (Church & White, 2006) is still considered unlikely this century but events in Greenland (Carlson, 2011; Gregory, 2004; Overland, 2011) and in Antarctica (Bentley, 1997; Thomas *et al.*, 2004) may soon force a re-evaluation of that assessment. In the longer term, the large-scale melting of large ice masses is inevitable. Recent literature (since IPCC, 2007) gives a wide range of SLR scenarios, as indicated in the figure below.



Comparison of minimum and maximum estimates of global SLR by 2100 (USACE, 2011) (NB: Post-2007 studies give an overall range of about 0.5 m to 2 m.)

Some projections and scenarios are even higher but most physics or process-based projections (Church et al., 2011; Milne et al., 2009; Nicholls & Cazenave, 2010; Pfeffer et al., 2008; SWIPA, 2011) for 2100 are in the 0.5 m to 2 m range, as also concluded in various reviews (Fletcher, 2009; Rossouw & Theron, 2009; Theron, 2011). It is concluded that the best estimate (mid-scenario) of SLR by 2100 is around 1 m, with a plausible worst-case scenario of 2 m and a best-case scenario of 0.5 m (Theron et al., 2012). These scenarios are applied in the INGC Phase II coastal protection study.

Figure 59 describes the study area.

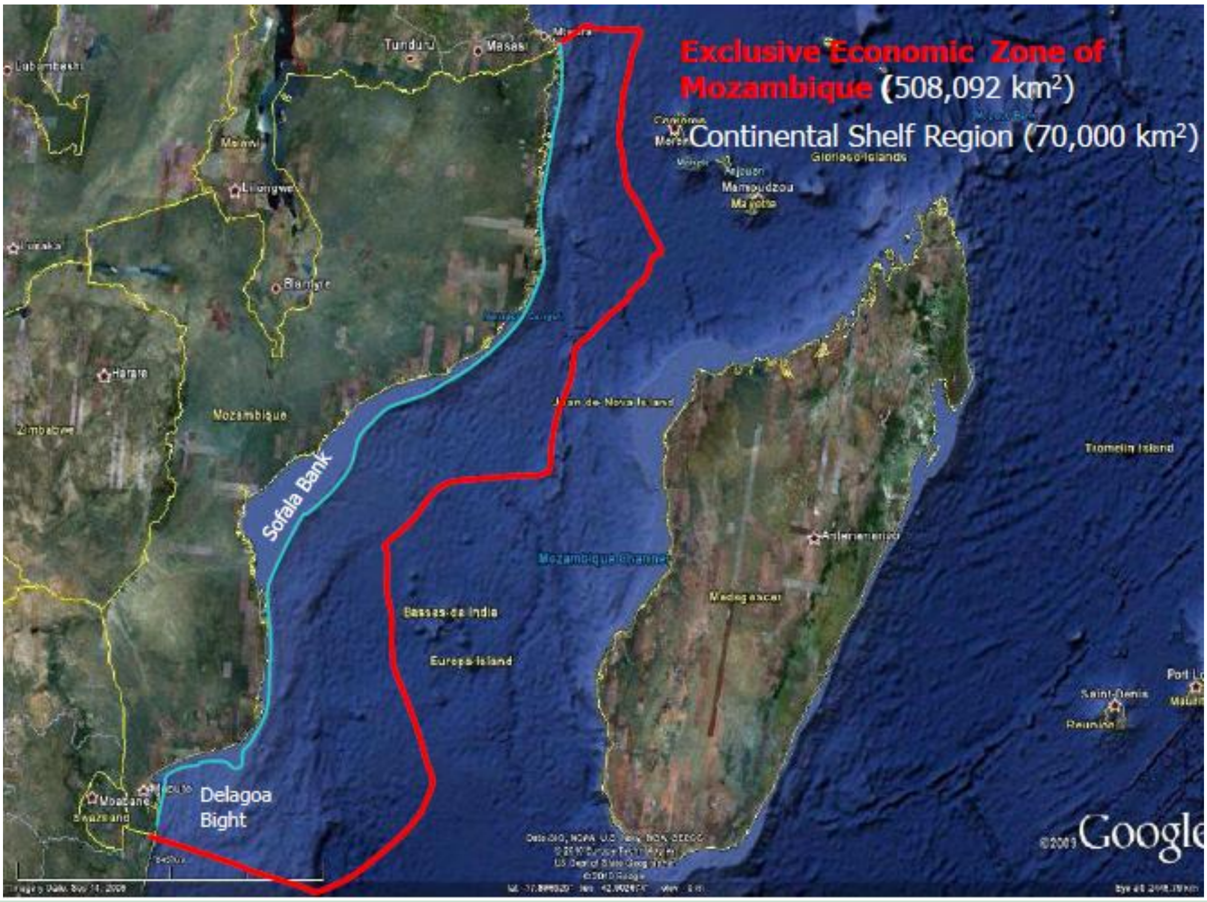


Figure 59: Study area covering the Mozambique Channel and the oceanic region around Madagascar

As can be seen from Figure 59, the Mozambique Channel is located in the south-western Indian Ocean between 12° south and 26° south latitude and 33° east and 40° east longitude. The region from the coast of Mozambique to the red-line boundary represents the oceanic waters of Mozambique (the Exclusive Economic Zones), which covers 508 092 km². The region between the coast and the thin blue line is the continental shelf of Mozambique, covering about 70 000 km². The two broadest continental shelf regions are the Sofala Bank and Delagoa Bight, which present unique marine ecosystems and contain the highest chlorophyll concentrations within the Mozambique oceanic waters, supporting important fisheries.

The Sofala Bank is a region of high river run-off, which leads to severe dilution of the ocean surface-waters (salinity close to the Zambezi River mouth is some 44% less than that at the far edge of the shelf). The high chlorophyll concentrations are due mainly to high nutrient loads injected by the various rivers running out onto the bank (Boge, 2006). Changes in river run-off due to climate or other factors would alter the availability and quality of fresh-water and nutrients in respect of the coastal and estuarine environment, with implications for productivity and ecosystem functions.

The Delagoa Bight circulation is a quasi-permanent cyclonic (clockwise) eddy. Its high chlorophyll concentrations are derived mainly from upwelled water from as deep as 900 m, bringing deep, cold, nutrient-rich water continuously to the surface (Lutjeharms & Da Silva, 1988).

The Indian Ocean as a whole shows the same mean warming trend as the global ocean (Levitus *et al*., 2005). This is projected to continue (IPCC, 2007). The warming of the Indian Ocean, however, is not homogeneous but exhibits geographically specific distributions of warming and cooling. Regions in the Indian Ocean from the equator to 10° south exhibit rapid cooling trends at the surface and sub-surface, whereas warming trends occur around 43° south and 23° south (Levitus *et al*., 2005).

For the Mozambican channel, situated between 12° south and 26° south, models give varying results. Of the six numerical models (Han *et al*., 2010, described in detail in the main INGC Phase II report), only half indicate SLR in the Mozambique Channel since 1958. Overall, however, caution in interpretation is needed, as reported data suffer from incomplete and short data sets.

The INGC Phase I study concluded the following:

> *The admittedly poor records available from Maputo from 1960-2001 are not inconsistent with the two estimates of regional trends from Church et al 2004, who identified regional patterns of sea level rise from global tide gauge records between 1950 and 2000. For Southern Africa, they estimated sea level rise of about 1.0 to 2.5 mm per year (this does not take into consideration sea level rise resulting from land subsidence which plays an important role in e.g. Central Mozambique). These rates are in agreement with earlier studies of observations from the west coast of South Africa by Brundrit (1995) and recent analysis of tide gauge records from Durban by Mather 2007.*

Church *et al.* (2004) comment as follows:

> *While significant progress has been made in observing the global oceans, clear deficiencies remain. The historical record is plagued by insufficient data, and new techniques for reanalysis of the historical ocean database of 1950 to present are needed to produce better regional projections of steric sea level change.*

A recent (2010) synthesis on understanding SLR and variability authored by approximately 80 scientists states that, while the regional distribution of SLR is important and satellite altimeter data show significant regional variations in the rate of SLR, the regional variation in the relatively short altimeter records is largely a result of climate variability. A chapter on distribution of SLR shows that, despite specific areas with negative values, in other words, sea level drop, the western Indian Ocean is overall continuing to rise. The report states that "during the 21st Century, climate variability will continue and coastal communities will be impacted by a combination of the pattern of long term sea level rise and the natural variability in sea level".

At present, the lack of regionally coupled atmosphere-ocean climate models is an impediment to the projection of future ocean climate trends in the Mozambique Channel with high accuracy. It is, however, possible to build two plausible scenarios based on the oceanographic climatology of the last 50 years and climate trends derived from numerical models and from global atmosphere and ocean models.

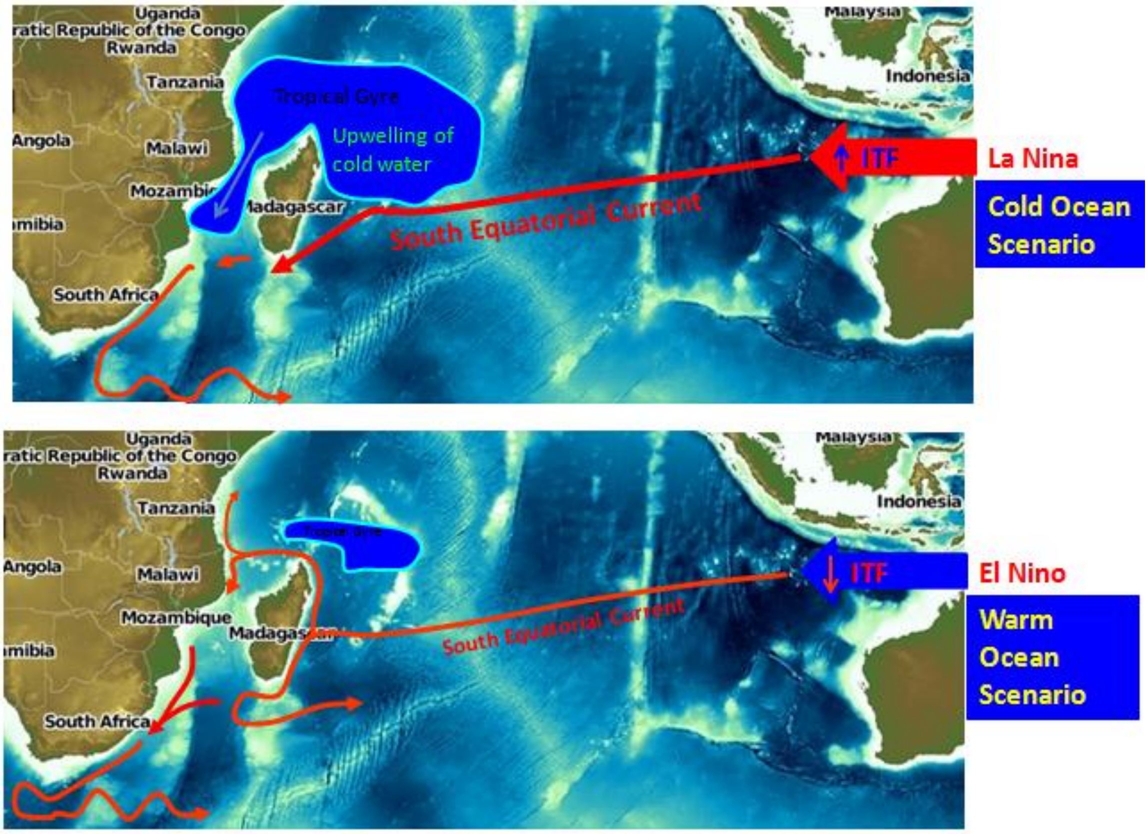


Figure 60: Warm and cold-ocean scenarios

The warm-ocean scenario depicted in Figure 60 is based on the continued streaming of the South Equatorial Current through the Mozambican Channel, as is currently the case. The South Equatorial Current, which transports equatorial and subtropical waters from the eastern Indian Ocean to the south-western Indian Ocean, flows zonally until it reaches the island of Madagascar, where it bifurcates into a northern and a southern branch (Schott et al., 2009).

The South Equatorial Current is the largest contributor of water masses to the Mozambique Channel (Ridderinkhof et al., 2010). The second-largest contributor is the Pacific Ocean via the Indonesian Throughflow (Ridgway & Dunn, 2007; Speich et al., 2007), which decreases in intensity with the ocean climate mode El Niño and increases in intensity with the ocean climate mode La Niña (Gordon, 2005).

The cool-ocean scenario is based on the southward displacement of the South Equatorial Current, pushed down by a larger south Indian Ocean tropical gyre. Changes in ocean temperature occur at a much slower pace than changes in land temperature.

The warmer-water ocean climate-change scenario is based on the assumptions that (i) the South Equatorial Current (the main supply source of upper-layer ocean water to the Mozambique Channel) will not change its present-day mean position and that (ii) the South Equatorial Current is warming in correlation with global warming trends[35]. Under such assumptions, it can be shown that increasingly warmer upper-layer waters will be supplied to the Mozambique Channel via the northern East Madagascar Current, leading to a warmer-water ocean climate compared to the present-day climatology. Such a warmer-water ocean climate-change scenario will induce higher temperatures and

[35] Rouault *et al*. (2010) show that the Agulhas Current system is warming at a rate of 0.7^{o} C per decade and that these increasing amounts of heat are derived from a warming South Equatorial Current.

lower salinities, an SLR and decreases in chlorophyll densities for the greater Mozambique Channel, including the Mozambique Exclusive Economic Zones. It is assumed that, under the warmer-water ocean climate-change scenario, the mean circulation pattern will remain the same as today, with the northern East Madagascar Current still being the main supply of warm upper-layer ocean waters to the Mozambique Channel.

The cooler-water ocean climate-change scenario is based on the assumptions that (i) the South Equatorial Current will migrate southwards from its present-day mean position and that (ii) the South Equatorial Current's warm equatorial waters will be diverted away from the northern Mozambique Channel inlet, supplying all its waters to the Agulhas Current via the south of Madagascar instead. Under such conditions, the south Indian Ocean tropical gyre, characterised by cooler-ocean waters, could then supply cooler waters to the Mozambique Channel through the northern inlet. This process could, in essence, induce a cooler-water ocean climate-change scenario compared with the warmer-water ocean climate-change scenario for the region. The cooler-water ocean climate-change scenario will entail a change in mean circulation, cooler sea temperatures, sea level fall and an increase in chlorophyll densities compared with the warmer water scenario (except from the Delagoa Bight to the South African-Mozambican border, where oligotrophic waters from the South Equatorial Current extension will lead to chlorophyll-poor ocean waters.

The El Niño ocean mode[36] is associated with the warm-ocean scenario, as it would lead to a reduced contribution of the Indonesian Throughflow to the Mozambique Channel waters. The South Equatorial Current would reach the island of Madagascar at about 20^{o} S and bifurcate into a northern and a southern branch (Schott *et al*., 2009). Warm tropical water is dispensed via the northern branch current around the northern tip of Madagascar into the Mozambique Channel. The opposite is true during La Niña modes, when the bulk of the South Equatorial Current is forced south of Madagascar and the tropical gyre intensifies and displaces southwards (De Ruijter *et al*., 2004; Gordon, 2005; Palastanga *et al*., 2006; Ridderinkhof *et al*., 2010).

In order to monitor ocean climate trends, it is necessary to engage in the long-term collection of data sensitive to ocean trends *over periods of decades*. Such instrument recordings would have to be made continuously without long periods of interruption. Ocean climate-change monitoring instruments would be relatively inexpensive to purchase. The combined monitoring of sea level and ocean temperature for the Mozambique Exclusive Economic Zones would be a reasonable monitoring system for the evaluation of whether a warmer-water or a cooler-water ocean climate would prevail over periods extending for decades.

Despite technological and scientific progress, the impacts of climate change on global marine capture fisheries and the associated supporting natural environment remain largely uncertain. This applies even more so to the scaled-down projections of the impact of climate change on fisheries on both a national and a sub-national scale.

Mozambique was previously rated as the eighth most vulnerable of 132 national economies to potential climate change impacts on their capture fisheries (Allison *et al*., 2009). According to Allison *et al*., the

[36] The El Niño and La Niña modes are due to changes in the coupled atmosphere-ocean system over the tropical Pacific (Schott *et al*., 2009). Anomalous increases (La Niña) and decreases (El Niño) in the equatorial easterlies of the eastern equatorial Pacific Ocean lead to shallower (La Niña) or deeper (El Niño) thermocline depths in this region, causing La Niña or El Niño events (Schott *et al*., 2009). These events impact on the ocean climates of all the major ocean basins in the world.

vulnerability of the national economies was due to the combined effect of predicted warming, the relative importance of the fisheries to the national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities.

In the case of Mozambique, climate change impacts on fisheries would not be confined to the industrial and semi-industrial sectors. The country has one of the largest artisanal-fisheries sectors in Africa, with 70 000 fishers operating from some 700 sites along the coast in all its coastal provinces. These fisheries are closely linked to vulnerable ecosystems, such as coral reefs, sea-grass meadows, mangrove ecosystems, estuaries and shallow coastal waters. Disruptions to the ecosystem services generated and the fisheries-resource base, in particular, could therefore have major socio-economic implications. As this sector lands an estimated 100 000 mt of fish annually, this would result in food security issues and impact on the livelihoods and well-being of the dependent communities.

Possible impacts on fisheries could be attributable to a variety of both direct and indirect effects from a number of physical and chemical factors, including temperature, winds, vertical mixing, salinity, oxygen and acidity (Brander, 2007). Some of the more obvious impacts would be a loss in diversity, changes to fish community composition, seasonality and, hence, the availability of traditional resources.

Notwithstanding the potential gravity of the issues, relatively little information is available on the specific and quantifiable impacts of climate change on fisheries on a national scale. Efforts were started to establish more information on the extent of the predicted impact on the capture fisheries of Mozambique and, subject to funding, will be continued during INGC Phase III. This will require coupling the ocean climate scenarios described above with the coastal climate scenarios on the shelf. While the ocean climate scenarios may be used to project the potential impacts of climate change on industrial or commercial fisheries, the coastal or near-shore climate scenarios may be used to predict the impact of climate change on subsistence or artisanal fisheries.

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Annex 1: Beira, Maputo and Pemba: Build-up of the three SLR scenarios and implications in terms of flooding levels and the vulnerability of infrastructure situated below the 5 m, 8 m and 10 m contour lines

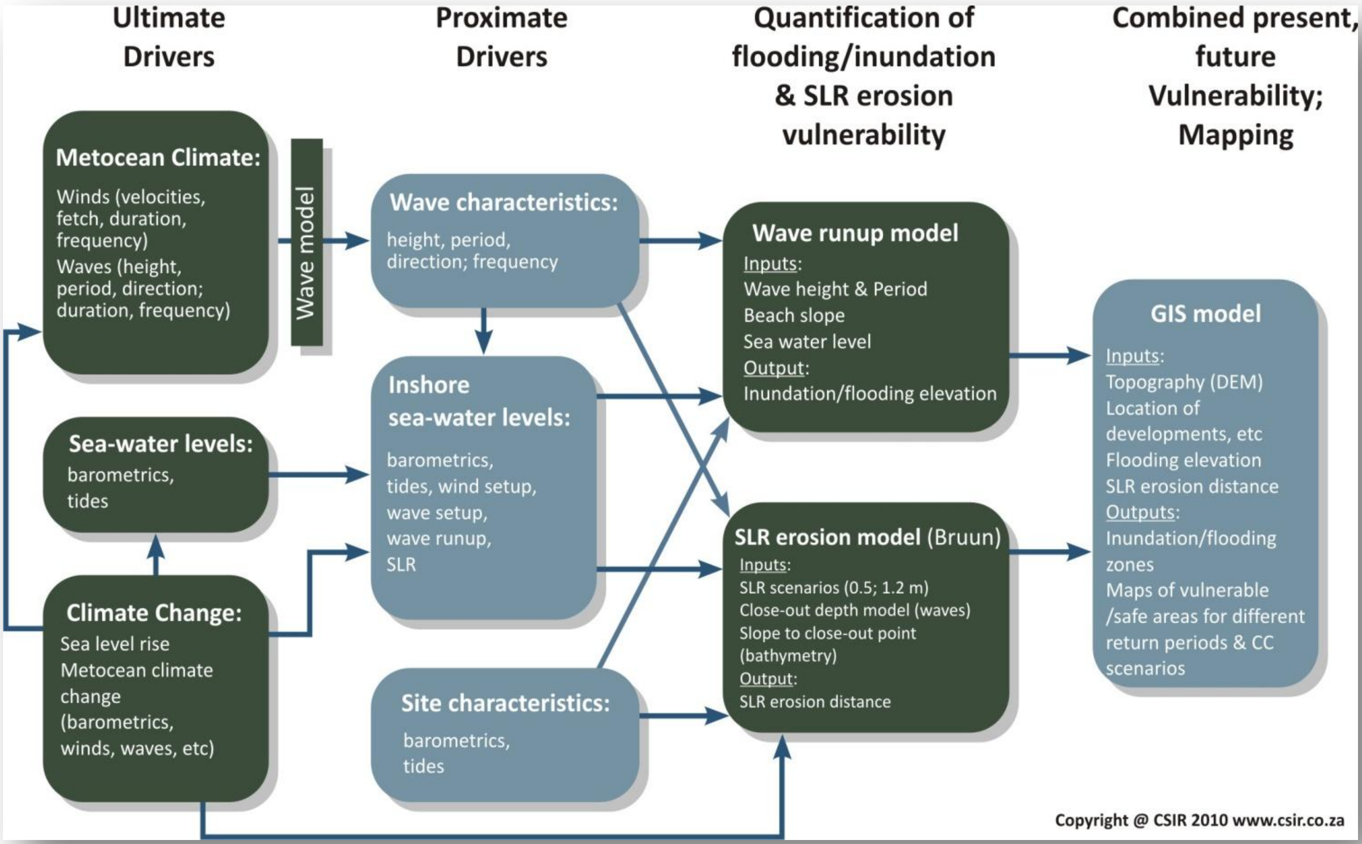
Climate change scenarios and associated levels of vulnerability	Beira	Maputo	Pemba	Associated hazard level
MSL (baseline, i.e. all water levels are relative to the MSL)	= 0 m elevation	= 0 m elevation	= 0 m elevation	
MHWS (this level occurs ± every 14 days for ± 18 hours each time)	2.9 m above MSL	1.5 m above MSL	3.3 m above MSL	
Crest elevation of existing coastal structures[37]	3.46 m above MSL	n/a (varies)	n/a	
MHWS with local barometric set up (additional sea-water body or level). *At present*, a cyclone approaching the city during spring tide (which occurs every two weeks) could result in an additional local increase in sea-water level (due to strong onshore winds and low barometric pressure) of a +2 m MHWS (flooding)[38].	4.9 m above MSL	3.5 m above MSL	5.3 m above MSL	**THE HIGH HAZARD ZONE is below the 5 m contour line. People and infrastructure below this level are already at risk.**
LOW SLR SCENARIO: MHWS with a 0.5 m SLR by 2050 or 1 m by 2100 (best estimate scenario). A cyclone during springtide with a 1 m SLR could result in flooding levels of a +2 m MHWS (flooding) plus a 1 m SLR.	5.9 m above MSL	4.5 m above MSL	6.3 m above MSL	Low SLR scenario (best case)
MEDIUM SLR SCENARIO: MHWS with a 0.5 m SLR by 2050 and wave run-up. A cyclone approaching the coast will cause storminess and high waves. Modelling shows an additional wave height of 1.5 m and upwards. (NB: This is *not* the same as the increase in water body described above.) A cyclone during springtide with a 1 m SLR, including wave elevation, could result in a +2 m MHWS (flooding) plus a 1 m SLR plus a 1.5 m wave run-up.	7.4 m above MSL	6.0 m above MSL	8.5 m above MSL	Medium SLR scenario THE INTERMEDIATE HAZARD ZONE is roughly between the 5 m and 8 m contour lines.
HIGH SLR SCENARIO: SLR of 1 m by 2050 or 2 m by 2100, with fully exposed shorelines and slopes	9.9 m above MSL	8.5 m above MSL	10.3 m above MSL	High SLR scenario (worst case)

[37] INGC Phase I, 2009.
[38] The combined wave and "barometric" set-up is estimated to be about 2 m (respectively 1 m each). For detailed justification, see sections 5.5.2 and 5.5.3 (pp 54–57) of the INGC Phase II report on coastal protection.

Climate change scenarios and associated levels of vulnerability	Beira	Maputo	Pemba	Associated hazard level
allowing for a 3 m wave run-up. A cyclone during springtide could create a wave elevation of +2 m MHWS (flooding) plus a 2 m SLR plus a 3 m wave run-up. Note: No accurate levels of recurrence can be attributed to such a combination of events (it can be more or less than a true 1:100 extreme event). This requires long-term water level recordings including during cyclones, which are insufficient for Mozambique. Following the precautionary approach, these plausible scenarios were robustly applied and serve as a first-level approximation.				THE LOW HAZARD ZONE is above the 10 m contour line.

Note: A comparison of the minimum and maximum estimates of global SLR by 2100 shows that the 2007 IPPC fourth assessment report predicts an approximate 0.4 m SLR by 2100. Post-2007 studies (such as Milne *et al*, 2009; Nicholls & Cazenave, 2010; Pfeffer *et al*, 2008; SWIPA, 2011), however, give an overall range of an approximate 0.5 m to 2 m SLR by 2100. This is also concluded in various reviews (such as Fletcher, 2009; Theron & Rossouw, 2009;). It is concluded that the best estimate (the mid-scenario) SLR by 2100 is around 1 m, with a plausible worst case scenario of 2 m and a best case scenario of 0.5 m. The corresponding best estimate (mid-scenario) projection for 2050 is a 0.3 m to 0.5 m SLR.

Annex 2: Combined coastal flooding/inundation and SLR erosion model applied to determine coastal set-back lines



Key: SLR = sea level rise; DEM = digital elevation model

The above is a conceptual description of the combined coastal flooding/inundation and SLR erosion model applied to determine coastal set-back lines and safe areas for different climate change scenarios. Once inshore wave conditions have been determined at each coastal point along the coast for various tidal levels combined with different wave heights, the wave run-up and SLR coastal erosion models can be employed to quantify specific coastal impacts.

NB: This model focuses on erosion resulting from SLR. Other factors contribute to erosion and must be taken into account in the determination of final set-back lines. See the INGC Phase II report on coastal protection for further details.

Annex 3: Vulnerability indicators applied to a detailed Mozambican coastal vulnerability assessment

#	Vulnerability criteria	Vulnerability classification and score				
		VL	L	M	H	VH
		1	2	3	4	5
1	TE: Elevation (m)	> 30	21–30	11–20	6 -10	<5
2	DS: Distance to shore (m)	> 1 000	200–1 000	50–200	20 -50	<20
3	TR: Tidal range (m)	< 1	1–2	2–4	4 – 6	>6
4	WH: Maximum wave height (m)	< 3	3–5	5–6	6 – 7	>7
5	EA: Erosion/accretion rate (m/yr)	> 0 (accretion)	-1 to 0	-3 to -1	-5 to -3	< -5 (erosion)
6	GL: Geology	Hard rocks (magmatic)	Medium-hard rocks (metamorphic)	Soft rocks (sedimentary)	Non-consolidated coarse sediment	Non-consolidated fine sediments
7	GM: Geomorphology	Mountains	Rocky cliffs	Erosive cliffs, sheltered beaches	Exposed beaches, Flats	Dunes, river mouths, estuaries
8	GC: Ground cover	Forest/ mangroves	Ground Vegetation, cultivated ground	Non-covered	Rural urbanised	Urbanised or industrial
9	AA: Anthropogenic actions	Shoreline stabilisation intervention	Intervention without sediment sources reduction	Intervention with sediment sources reduction	Without intervention or sediment sources reduction	Without intervention but with sediment sources reduction
10	Degree of protection from prevailing wave energy	Leeside of large island or extensive spit on opposite side of wave-incident waves	Leeside of headland, rocky point or peninsula	Partially sheltered from deep-sea wave energy	Directly exposed to waves only slightly refracted from deep-sea	Directly exposed to storm wave attack, with narrow surf zone
11	Cyclones (occurrence/a)	0	> 0 < 1	1–2	>2-3	>3
12	SLR Bruun erosion potential (inshore slope)	< 0.1 (1/10)	0.1–0.029	0.03–0.014	0.015-0.005	>0.005
13	Corals/fringing reefs (alongshore extent as % of	< 10	10–30	30–50	50-80	>80

#	Vulnerability criteria	Vulnerability classification and score				
		VL	**L**	**M**	**H**	**VH**
		1	**2**	**3**	**4**	**5**
	total length)					
14	Relative height (m) of protective foredune buffer	> 20	10–20	5–10	0.5-5	<0.5

SLR scenarios used for the detailed vulnerability analysis

#			Excluding cyclones			Including cyclones	
			Present wave climate	Increased storminess		Present wave climate	Increased storminess
			1	2		3	4
No climate change:		A	Present wave climate	Present wave climate		Present wave climate	Present wave climate
Climate change included	SLR = 0.5 m	B	Present wave climate	Increased storminess		Present wave climate	Increased storminess
	SLR = 1.0 m	C	Present wave climate	Increased storminess		Present wave climate	Increased storminess
	SLR = 2.0 m	D	Present wave climate	Increased storminess		Present wave climate	Increased storminess
Note:		Scenario A1 is the same as A2, therefore no A2 scenario is included in the scoring. Scenario A3 is the same as A4, therefore no A4 scenario is included in the scoring.					

The vulnerability of coastal locations increases as the scenarios increase from A to D. Scenario A is without climate change. Scenario B is the low climate change scenario. Scenario C3 is the best estimate climate change scenario. Scenario D4 is the worst case scenario.

Annex 4: Estimated costs of priority coastal adaptation measures

I. COMPARATIVE FUNCTIONALITY/SUITABILITY/COST OF SOME POTENTIAL ADAPTATION MEASURES

Suitability criteria / Adaptation alternative	Shoreline stability	Wave attenuation potential	Inundation due to SLR mitigation potential	Environmental and social impact	Relative cost	Relative design life	Maintenance cost	Maintenance frequency
~~Do nothing~~	~~Low~~	~~Nil~~	~~Nil~~	~~Nil to high~~	~~Nil~~	~~–~~	~~–~~	~~–~~
Shoreline nourishment	Medium to high	Low to high	Low to high	Low	Medium to high	Short to medium	Medium	Medium
Revetment	High	High	High	High	High	Long	High	Low
Detached break-water	Limited	Limited	Nil	Medium	Medium to high	Long	High	Low
Sill	Medium to high	Medium	Low	Medium	Medium	Long	Medium	Low
Sub-merged break-water	Limited	Limited	Nil	Low to medium	Medium to high	Long	Medium	Low
~~Wave fence– fully reflective~~	~~Medium to high~~	~~High~~	~~Nil~~	~~Medium to high~~	~~Low to medium~~	~~Medium~~	~~Low~~	~~High~~
Wave fence– ~~partially reflective~~	Medium	High	Nil	Medium	Low to medium	Medium	Low	Medium
~~Floating break-water~~	~~Medium~~	~~Medium~~	~~Nil~~	~~Low to medium~~	~~Medium~~	~~Medium~~	~~Medium~~	~~High~~

Note: Effectiveness, impacts and costs can vary significantly due to local site characteristics, the availability of materials, access and transport costs.

II. SUMMARY OF SOME ADAPTATION OPTION COST ESTIMATES*

Description	Approximate minimum costs (excluding tax) for 1 km	Approximate maximum costs (excluding tax) for 1 km	Approximate minimum costs (excluding tax) for 10 km	Approximate maximum costs (excluding tax) for 10 km
Sand feeding (beach nourishment) new @ rate of 300 000 m^3/a for 10 yrs)	$4 000 000	$60 000 000	$40 000 000	$600 000 000
Sand feeding (beach nourishment) maintenance	$400 000?	$7 780 000?		
Revetments and walls (permeable)	$2 300 000	$24 000 000	$23 000 000	$240 000 000
Vegetated dune	$750 000	$7 200 000	$7 500 000	$72 000 000
Geotextile sand containers, geobags (semi-sheltered location)	$1 100 000	$23 000 000	$11 000 000	$230 000 000
Gabions (semi-sheltered location)	$600 000	$7 000 000	$6 000 000	$70 000 000
Rock groynes	$1 000 000	$29 200 000	$10 000 000	$292 000 000
Wave fence (semi-sheltered location)	$2 300 000	$40 000 000	$23 000 000	$400 000 000
Floating pontoons (semi-sheltered location)	$2 250 000	$31 600 000	$22 500 000	$316 000 000
Rubble mound breakwater structure, land-based	$1 500 000	$15 100 000	$15 000 000	$151 000 000
Rubble mound breakwater, marine-based	$2 900 000	$42 800 000	$29 000 000	$428 000 000
Sheet-piling sea wall (shore parallel)	$2 700 000	$36 000 000	$27 000 000	$360 000 000

** Adapted from South African experience and supplemented by some experience in other African countries and limited international input.*

Explanation of the difference between minimum and maximum estimates

There are many local factors and other details, such as local supplier pricing, which will have a big impact on project costs. These can be assessed properly only at the detail design stage of specific projects.

A significant proportion of the costs for most of the coast protection materials lies in transport and placement. Work on dune systems can impose additional costs due to concerns over the destruction of landforms and habitats, and the problems of working in locations lacking access. Delivery from the sea of bulk materials (rock or beach sediment) is therefore often preferred, as backshore damage is minimised, although land access will still have to be provided for plant, labour and additional materials.

Parts of the Mozambican coast are very exposed or have very shallow inshore areas and sea access is therefore very difficult (expensive and risky). Haul roads will have to be built across the dunes unless access can be provided from an existing route. (Rock supply, plant availability and access are big cost factors especially relevant to parts of Mozambique.)

Besides direct capital costs, it is critical to consider the maintenance costs and life expectancy of the option. *Solutions MUST be sustainable*, which means that the recommended options must also be durable and affordable to the municipality and/or state (or responsible authority).

Note: It should be reiterated that, in the selection of adaptation options, it is very important for consideration to be given to the impacts on habitat, landform, landscape, coastal processes etc. Consideration should also be given to the full life environmental impacts of proposed management interventions and operations.

III. MAPUTO: COASTAL CONSTRUCTION CAPITAL COST ESTIMATES (2011)

Possible order of implementation	Description	Approximate minimum costs (excluding tax) for 1 km	Approximate maximum costs (excluding tax) for 1 km	Approximate length (or number of) proposed for Maputo (km)	Approximate minimum costs (excluding tax) for Maputo	Approximate maximum costs (excluding tax) for Maputo
1	Sand feeding (beach nourishment) new* @ rate of 300 000 m^3/a for 10 yrs	$4 000 000	$60 000 000	1	$4 000 000	$60 000 000
3	Revetments and walls (permeable)	$2 300 000	$24 000 000	2.7	$6 210 000	$64 800 000
4	Vegetated dune	$750 000	$7 200 000	6	$4 500 000	$43 200 000
2.5	Sheet-piling sea wall (shore parallel)	$2 700 000	$36 000 000	8.7	$23 490 000	$313 200 000
2	Heightening of quay walls, berths and other port infrastructure	$2 000 000	$25 000 000	6	$12 000 000	$150 000 000
Potential total cost of implementing all of the above (US$)					$50 200 000	$631 200 000

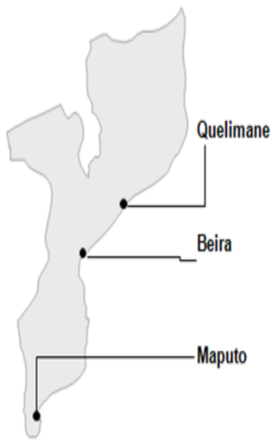
NB: The costs of the management options (A1 to A4), e.g. relocation and the alternative development of infrastructure, are not included.
* Actual nourishment to a point by means of pipelines with booster pumps from a dredger quay or distributed by means of dredger rainbowing off beaches.

IV. BEIRA: COASTAL CONSTRUCTION CAPITAL COST ESTIMATES (2011)

Possible order of implementation	Description	Approximate minimum costs (excluding tax) for 1 km	Approximate maximum costs (excluding tax) for 1 km	Approximate length (or number of) proposed for Beira (km)	Approximate minimum costs (excluding tax) for Beira	Approximate maximum costs (excluding tax) for Beira
2	Sand feeding (beach nourishment) new* @ rate of 300 000 m^3/a for 10 yrs	$4 000 000	$60 000 000	1	$4 000 000	$60 000 000
5	Revetments and walls (permeable)	$2 300 000	$24 000 000	2.3	$5 290 000	$55 200 000
4	Rock groynes**	$1 000 000	$29 200 000	1	$1 000 000	$29 200 000
3	Sheet-piling sea wall (shore parallel)	$2 700 000	$36 000 000	3.5	$9 450 000	$126 000 000
3	Heightening of quay walls, berths and other port infrastructure	$2 000 000	$25 000 000	3.5	$7 000 000	$87 500 000
Potential total cost of implementing all of the above (US$)					$26 740 000	$357 900 000

NB: The costs of the management options (A1 to A4), e.g. relocation and the alternative development of infrastructure**, are not included.**
* Actual nourishment to a point by means of pipelines with booster pumps from a dredger quay or distributed by means of dredger rainbowing off beaches.
** Cost estimate for one long groyne or two shorter groynes.

Annex 5: Maputo, Beira and Quelimane: Vulnerability analysis

Item	Maputo	Beira	Quelimane
Short description of the three cities 	Capital and largest city of Mozambique. Port city. Population = 1.2 million in 2010. GDP = US$1.6 billion in 2010 (US$1 300/capita). Total area = ± 308 km^2, divided into 57 neighbourhoods. 75% of residents live in informal settlements on periphery of city. Average temperature = 22 °C; average precipitation = 761 mm/yr. Rainy and cyclone season from November to March.	Second-largest city of Mozambique. Port city. Population = 440 000 in 2010. GDP = US$439 000 in 2010 (US$997/capita). Divided into 26 neighbourhoods. ± 75% of residents live in informal settlements on periphery of city. Average temperature = 28 °C; average precipitation = 1 478 mm/yr. Rainy and cyclone season from October to February.	Seventh-largest city of Mozambique. Inland port city (Rio dos Bons Sinais, Zambezia). Population = 204 000 in 2010. GDP = US$191 000 in 2010 (US$934/capita). Divided into 50 neighbourhoods. ± 75% of residents live in informal settlements on periphery of city. Average temperature = 25 °C; average precipitation = 1 652 mm/yr. Rainy and cyclone season from October to February.
Natural hazards have caused significant damage in recent years.	In 2000, Cyclone Eline caused the evacuation of 8 400 people from their homes and nearly US$100 million in damages, destroying chunks of the coastal road (Avenue Marginal) and flooding the Costa do Sol area. In 2005, strong winds destroyed 912 homes and damaged schools, health facilities etc. A total of 24% of peri-urban Maputo is infected with malaria, resulting in an average of 238 000 cases per year from 1999 to 2010.	In 2000, Cyclone Eline caused the evacuation of approximately 20 000 people from their homes and nearly US$60 million in damages. In 2006, strong winds destroyed 90 homes and damaged schools, health facilities etc. A total of 27% of urban Beira is infected with malaria annually, resulting in an average of 118 000 cases per year from 1999 to 2010.	In 2007, floods and winds caused 21 deaths and the evacuation of approximately 16 000 people from their homes and destroyed approximately 100 schools and 3 000 houses. A total of 37% of urban Quelimane is infected with malaria annually, resulting in an average of 77 000 cases per year from 1999 to 2010.
The three cities are highly vulnerable to climate-related hazards but focused	The highest expected loss is from inland flooding, followed by coastal flooding.	The highest expected loss is from coastal flooding, which would	The highest expected loss is from inland flooding, followed by epidemics (e.g. malaria).

Item	Maputo	Beira	Quelimane
adaptation actions can avert the majority of expected losses.		become devastating under high climate change scenarios, followed by inland flooding.	
Assets and income are estimated to increase threefold by 2030 through economic growth.	Assets (residential, commercial and industrial) are estimated to increase from US$6.5 billion in 2010 to approximately US$21.2 billion by 2030. Income (GDP) is estimated to increase from US$1.6 billion in 2010 to US$5.2 billion in 2030. The population is expected to increase from 1 253 000 in 2010 to approximately 1 984 000 by 2030.	Assets (residential, commercial and industrial) are estimated to increase from US$2.9 billion in 2010 to approximately US$13.6 billion by 2030. Income (GDP) is estimated to increase from US$439 million in 2010 to US$2 050 million by 2030. The population is expected to increase from 440 000 in 2010 to approximately 1 003 000 by 2030.	Assets (residential, commercial and industrial) are estimated to increase from US$712 million in 2010 to approximately US$3 323 million by 2030. Income (GDP) is estimated to increase from US$191 million in 2010 to US$893 million in 2030. The population is expected to increase from 205 000 in 2010 to approximately 466 000 by 2030.
Current economic growth trends are likely to increase exposure to natural hazards in the future.	Coastal vulnerability is currently approximately 7% of asset value at risk. Increasing assets in low-lying areas are prone to coastal flooding: US$92 million for a new development in the low-lying Costa do Sol area were approved in 2010; US$73 million for a new development on fragile, erosion-prone slopes in the Sommershield and Polano Cimento areas were approved in 2010; there is an active proposal to build a bridge connecting Maputo to Catembe, boosting development in low-lying Catembe. Total assets in Maputo are estimated at US$2.5 billion in 2010 and US$21.2 billion by 2030.	Coastal vulnerability is currently approximately 20% of asset value at risk. Certain assets are at risk: the increasing construction of new housing in the low-lying, swampy Chota and Macurungo areas not built to code; the increasing construction of condominiums, apartments, hotels and restaurants in (coastal) flood-prone Palmeiras and the Macuti area. Coastal flooding impacts heavily on the Beira (Ponta Gea, Macuti and Mananga) economic and residential centre. Flooding also impacts heavily on the Chaimite, Pioneiros and Munhava industrial areas. Eroding coastal roads are frequently rendered impassable in heavy rains.	There is no coastal vulnerability but there is significant risk from inland flooding to over 20% of the surface area. Certain assets are at risk: increasing developments not built to code in the Munhaua, Chuabo and Dembe erosion-prone areas; the Icidua, Mirazane and Ivagalane inland and river flood-prone areas. The downtown business district is less at risk from flooding.

Item	Maputo	Beira	Quelimane
Scenarios of climate change impact on the frequency and severity of hazards. Note: The maximum sea levels mentioned here do not include wave effects, which will increase these values further (see the INGC Phase II report on coastal protection for a detailed analysis on SLR).	A 274 cm maximum sea level currently expected every 100 years would occur approximately every 50 years under the moderate climate change scenario and approximately every 25 years under the high climate change scenario. The new maximum would be 292 cm[1] every 100 years in the moderate scenario, affecting residential areas more than commercial areas. Wind speeds would increase in frequency and intensity but still be at a relatively low level compared to Quelimane and have a relatively small impact.	A 445 cm maximum sea level currently expected every 100 years would occur approximately every 50 years under the moderate climate change scenario and approximately every 15 years under the high climate change scenario. The new maximum would be 470 cm under the moderate scenario. Storm wind speeds of 159 km/h expected every 100 years in today's climate could increase to 181 km/h every 100 years under the high climate change scenario. Temperature would increase more in Beira than the other two cities.	Storm wind speeds of 216 km/h expected every 100 years in today's climate could increase to 247 km/h every 100 years under the high climate change scenario. The vulnerability of damage to wood-frame housing and low-rise masonry would triple. Precipitation could increase from 3 mm/week under the moderate scenario to 8.4 mm/week under the high scenario during the December to March period.
Losses from climate-related events are expected to increase significantly.	The current expected loss of approximately US$50 million could increase to between approximately US$160 million and US$275 million or between 3.5% and 5% of GDP* by 2030 (3.5% under the moderate climate change scenario and 5% under the high climate change scenario). This average can mask the potentially devastating impact of lower-frequency events, the intensity of which is expected to increase under climate change.	The current expected loss of approximately US$20 million could increase to between approximately US$95 million and US$185 million or between 5% and 9% of GDP* by 2030. This average can mask the potentially devastating impact of lower-frequency events, the intensity of which is expected to increase under climate change.	The current expected loss of approximately US$8 million could increase to between approximately US$40 million and US$45 million or between 4% and 5% of GDP by 2030. This average can mask the potentially devastating impact of lower-frequency events, the intensity of which is expected increase under climate change.
Transport, housing and medical services are the sectors most at risk from climate change effects.	Risks are flash floods from, for example, the Umbeluzi River and landslides on high slopes. At risk are flood-prone access and unpaved roads. The main administrative buildings and majority of	Risks are coastal and inland floods in the Chota and Macarungo areas and coastal road erosion. At risk are flood-prone unpaved access roads. The main administrative buildings	At risk from inland flooding are housing in Icidua and Chuabo-Dembe. Unpaved roads become impassable with heavy rains and many paved roads are susceptible to erosion. The main administrative buildings and

Item	Maputo	Beira	Quelimane
	businesses and hotels are in safe areas. The areas most vulnerable to coastal and inland flooding can be seen in the main report. (*see coastal protection in the main INGC Phase II report for a detailed analysis*). Health data indicate a reduction in malaria cases but also a significant relationship with temperature, with approximately 900 new monthly cases per additional 1° C temperature[39].	and majority of businesses are in safe areas but some hotels and tourist facilities, especially new constructions, are vulnerable to coastal flooding. The areas most vulnerable to coastal and inland flooding can be seen in the main report (*see the INGC Phase II report on coastal protection for a detailed analysis*). Malaria findings are similar to those for Maputo.	majority of businesses and hotels are in safe areas. The areas most vulnerable to inland flooding can be seen in the main report (*see the INGC Phase II report on coastal protection for a detailed analysis*). Health data indicate a reduction in malaria cases but also a significant relationship with temperature, with approximately 350 new monthly cases per additional 1° C temperature.
Priority adaptation measures were identified for each city. Selection criteria applied included local authority consultations, community consultations, engineering perspectives and economic cost benefit. See the INGC Phase II report on coastal protection for a detailed analysis on coastal measures.	Priority measures include coastal and inland zoning, mangrove revival, inland and coastal drainage improvements (at Costa do Sol and Baixa), land bank reinforcement (at Polana Cimento and Polana Canico), building codes (in flood-prone neighbourhoods), bed-net distribution and indoor residual spraying.	Priority measures include coastal and inland zoning, mangrove revival (at Praia Nova), beach nourishment (at, for example, Palmeiras), groyne and sea wall rehabilitation (at Palmeiras, Chaimite, Pioneiros and Pta Gea), building codes (in, for example, Chota and Mucurungo), inland drainage (at Chota, Esturro, Mananga and Matacuane), coastal flood proofing, land bank reinforcement, bed-net distribution and indoor residual spraying.	Priority measures include inland zoning (at Icidua and Chuabo-Dembe), river mangrove replanting (at Icidua), inland drainage improvement (at Chuabo-Dembe and the Millennium Challenge Account drainage project zone), building codes (also for strong winds), wind retrofit buildings, bed-net distribution and indoor residual spraying.
Investment in adaptation will significantly reduce economic loss from disasters by 2030.	Adaptation and mitigation measures would allow Maputo to reduce the economic impact of disasters by approximately 37% under the moderate climate change scenario. Net loss averted in Maputo with cost-effective	Adaptation and mitigation measures would allow Beira to reduce the economic impact of disasters by approximately 43% under the moderate climate change scenario. Net loss averted in Beira with cost-	Adaptation and mitigation measures would allow Quelimane to reduce the economic impact of disasters by approximately 37% under the moderate climate change scenario. Net loss averted in Quelimane with cost-effective adaptation measures would total

[39] Note that the actual relationship is complex and dependent on many factors, the conclusions of the regression model being indicative. Cholera shows some observed positive correlations to increased temperature, rainfall and salt-water incursion but the baseline is dramatically lower than for malaria for all three cities.

Item	Maputo	Beira	Quelimane
	adaptation measures would total approximately US$75 million by 2030 (with the cost of adaptation measures already deducted).	effective adaptation measures would total approximately US$50 million by 2030 (with the cost of adaptation measures already deducted).	approximately US$15 million by 2030 (with the cost of adaptation measures already deducted).
Despite a strong economic rationale, adaptation measures represent a very significant investment.	Cost-effective adaptation measures (with a cost-benefit ratio of less than 1.5) would require an investment of approximately US$400 million in capital expenditure over the next five years. The majority would be spent on inland flood protection measures.	Cost-effective adaptation measures (with a cost-benefit ratio of less than 1.5) would require an investment of approximately US$270 million in capital expenditure over the next five years. The majority would be spent on coastal flood protection measures.	Cost-effective adaptation measures (with a cost-benefit ratio of less than 1.5) would require an investment of approximately US$40 million in capital expenditure over the next five years, spent on inland flood protection measures.
Much of the cities' expected loss is not covered by risk mitigation or prevention measures, pointing to the need for a risk transfer programme.	A total of 47% of expected losses is not covered by adaptation measures; these are mainly low-frequency events with high damage potential (51% of losses can be covered by cost-effective adaptation options and 3% can be covered only by non-cost-effective adaptation options).	A total of 39% of expected losses is not covered by adaptation measures; these are mainly low-frequency events with high damage potential (58% of losses can be covered by cost-effective adaptation options and 3% can be covered only by non-cost-effective adaptation options).	A total of 37% of expected losses is not covered by adaptation measures; these are mainly low-frequency events with high damage potential (48% of losses can be covered by cost-effective adaptation options and 15% can be covered only by non-cost-effective adaptation options).
The adaptation strategy for Maputo, Beira and Quelimane should combine risk prevention with risk transfer measures for less-frequent events (but with high damage potential), through, for example, parametric insurance.	The total cost of insurance[40] by 2030 could range from US$11 million to US$35 million, depending on the cost scenario selected. The cost-benefit ratio is quite poor in all scenarios (with a cost benefit of four to five), particularly when compared with other direct prevention measures.	The total cost of insurance by 2030 could range from US$6 million to US$17 million, depending on the cost scenario selected. The cost-benefit ratio is quite poor in all scenarios (with a cost benefit of four to five), particularly when compared with other direct prevention measures.	The total cost of insurance by 2030 could range from US$9 million to US$17 million, depending on the cost scenario selected. The cost-benefit ratio is quite poor in all scenarios (with a cost benefit of four to five), particularly when compared with other direct prevention measures.
A comprehensive adaptation strategy	Emphasis is on planning and resource	Projects that are highly feasible and	Update the city master plan to incorporate the

[40] These prices represent a conservative estimate (i.e. they are on the high side), as the risk premiums considered are those of cat bonds analysed by the World Bank typically above reinsurance industry risk premiums.

Item	Maputo	Beira	Quelimane
and implementation plan are needed to allow Mozambican cities to achieve their climate resilience ambition level of curbing losses due to climate change to 50% of current levels by 2030.	mobilisation, on timing and geographic focus for high-priority adaptation measures, on pushing already planned or funded measures and on the increased enforcement of the management oversight of new measures.	have a low cost-benefit ratio should be pursued first before others are implemented. Capital expenditure and expected averted loss depend on the insurance coverage scenario and adaptation measures implemented (with a cost-benefit ratio cut-off).	climate change adaptation plan and the zoning of vulnerable areas. Complete the regularisation of land tenure as a foundation for proper zoning in flood-prone areas (such as Icídua and Chuabo-Dembe).

* Maputo-projected GDP by 2030 is US$5.2 billion, Beira-projected GDP by 2030 is US$2.0 billion and Quelimane-projected GDP by 2030 is US$0.9 billion.

Expected loss per climate change scenario is a product of hazard (severity and frequency) of value (assets, income and human elements) and of vulnerability (different assets based on hazard severity).

Annex 6: Best-practice city analysis

Three cities were identified[41] outside Mozambique that could serve as examples of successful adaptation planning, implementation and governance. The following two tables summarise the comparison and best practices of use to Mozambique.

Issue	Durban (South Africa)	Amsterdam (the Netherlands)	Monterrey (Mexico)
Adaptation strategies	Adaptation is part of a city-wide strategic plan.	The national adaptation strategy of 2007 aims to integrate local policies by 2015.	The state of Nuevo Leon (NL) sets strategies and policies (Monterrey is the capital of NL).
Policies	Policies on urban interventions (such as green roofs)are in place.	Policies on, for example, spatial planning and risk assessment are still being developed.	More flood-resistant infrastructure planning is being done.
Prioritised adaptation projects	By expert opinion and “instinct”; practicality and capacity of staff; economic analysis	n/a	Economic criteria, such as the effect on employment
Responsible authorities	The mayor is the political champion of adaptation. A climate protection branch (with three staff members: a manager, a scientist and an environmental technician) is part of the environmental planning department, which is one of six departments under the mayor.	The city of Amsterdam is divided into regions. A regional government of Amsterdam will work with task forces to develop adaptation plans for specific areas of Amsterdam and report to the mayor. Privatised strategic industries must comply with regulations.	The NL development secretariat has authority for planning and transport and covers disaster risk management. It works with the mayors of the 10 municipalities.
Coordination with other departments	The development of adaptation champions in other departments is	Three departments – water control, spatial planning and environment,	Coordination takes place between the NL development secretariat and the mayors.

[41] The cities were selected on the basis of their hazard profile (similar to that of Mozambique; high-priority weighting), their governance level (a high-quality governance level to serve as good examples of effective planning and implementation; high-priority weighting) and their development level (with similar resource constraints and infrastructure challenges; medium or low-priority weighting – this criterion was often at odds with the governance criterion and the latter prevailed).

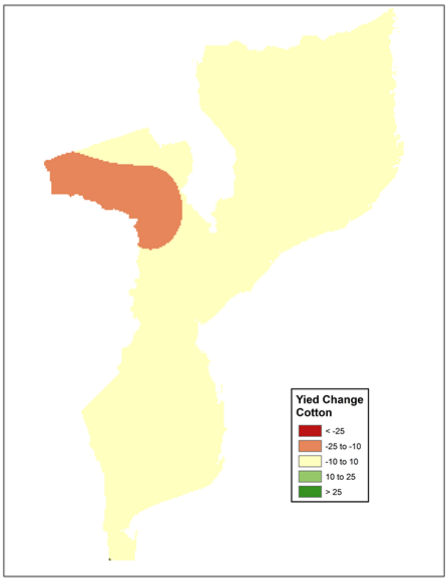
Issue	Durban (South Africa)	Amsterdam (the Netherlands)	Monterrey (Mexico)
	critical. Links with water and DRM departments are good.	and construction – are responsible but there is little integration.	
Private-sector involvement	Private-sector engagement is much greater in greenhouse-gas mitigation than in adaptation. Large industry players are unlikely to act without national legislation. There are no incentives.	There is interaction with the private sector on risk prevention. Risk prevention regulations are in place for new industrial infrastructure. The "Rainproof 2015" programme contains rules on surface and rain water collection. There are incentives (subsidies) for green roofs (to store water) and preventive actions (such as dykes).	Private-sector engagement is greater in greenhouse-gas mitigation than in adaptation. Regulations on building on mountainsides and on the increased resilience of bridges are in place. Companies must have insurance.
Financial regulations	An insurance policy covering extreme events is in place. There is no explicit climate-related component to the city's insurance.	An insurance policy covering extreme events is in place for the city of Amsterdam. There is no explicit climate-related component to the city's insurance.	The state of NL insures economically important assets, such as roads, against natural disasters. City insurance against natural disasters (covering approximately US$1.15 million in 2012) is in place. There is no explicit climate-related component to the city's insurance.

Key learnings for Mozambique from the best-practice city analysis

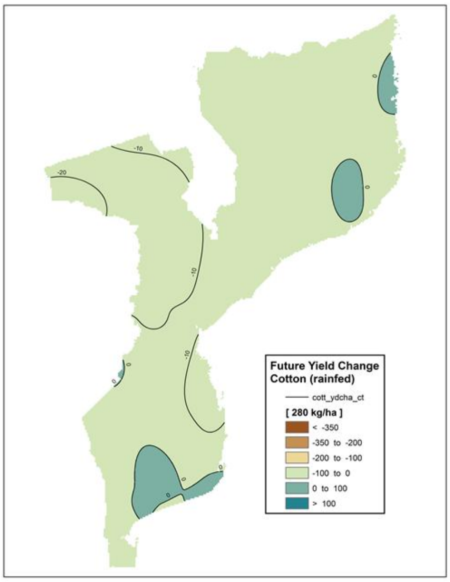
Key learning	Rationale	Applicability to specific sites
Get political backing from the highest possible level.	Powerful city mayors in Mozambique are not yet fully engaged in adaptation.	Maputo: Ensure the resilience of the road bridge crossing water at Catembe. Regulate development on erosion slopes.
Take advantage of natural disasters to accelerate the awareness-building process and change planning strategies.	Recent, very disruptive events in all three cities are still in the public memory.	Maputo, Beira: Use recent extreme weather events as catalysts for action, such as the improvement of building codes and the resilience of planned urban developments.
Create adaptation champions in municipal departments.	No strong climate adaptation unit exists in any of the three cities. More important than a specific city department dedicated to climate change adaptation is having individuals dedicated to climate change adaptation in the most relevant municipal departments (planning, infrastructure, health etc.) with the skills and empowerment to drive the climate change agenda – true climate change adaptation champions spread throughout the municipal structure.	Quelimane: Learn from Durban when updating the city master plan to include adaptation. Look at the Amsterdam and Monterrey experience in protection against inland flooding.
Engage companies as part of wider climatic and regulatory discussions and foster business champions.	In the face of fast urban and industrial development, engagement and cost sharing with the private sector is a necessity. Close private-sector involvement is a very strong driver of climate change adaptation success and could be achieved by engaging companies in regulatory discussions and striving to have visible business champions of climate adaptation.	

Key learning	Rationale	Applicability to specific sites
Start thinking about financial regulations, such as insurance at municipal level.	Insurable losses are significant in all three cities and would benefit greatly from risk transfer mechanisms. Financial strategies could take the form of municipal insurance but also of regulations on compulsory insurance for private assets.	
Conceive climate action holistically, with clear ownership at municipal level. Divide the holistic strategy into sectorial strategies and include these into sectorial planning tools.	Durban's experience is worth evaluating and potentially testing.	

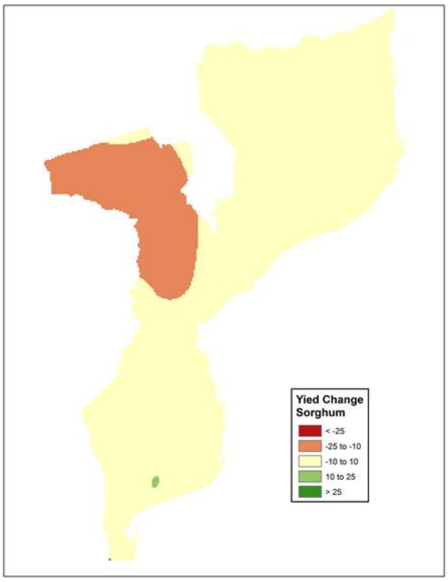
Annex 7: Geographical distribution of projected changes in crop yield for 2046 to 2065



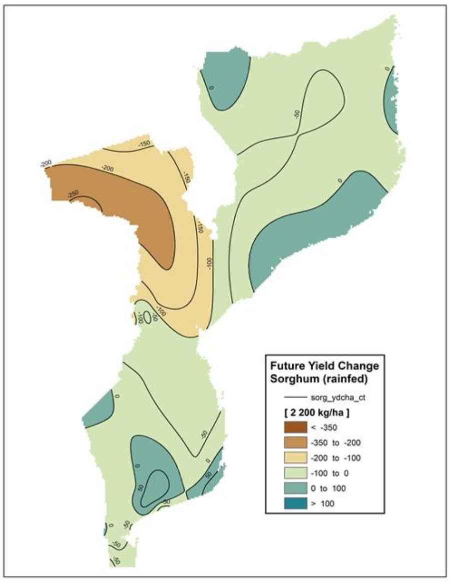
Projected future changes (2046–2065) for cotton (median of all 7 GC-MSs), expressed in % of present yields



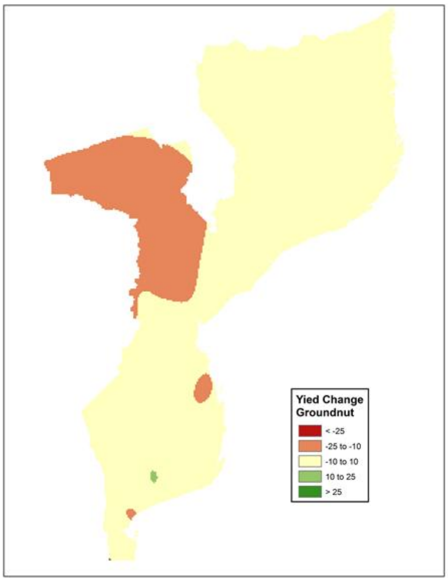
Projected future changes (2046–2065) for cotton (median of all 7 GC-MSs), expressed in kg/ha



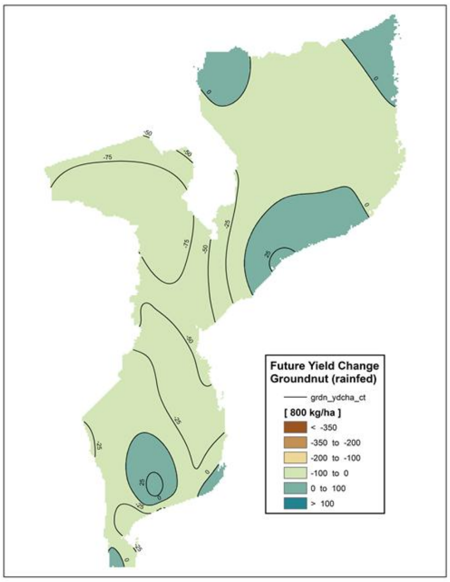
Projected future changes (2046–2065) for sorghum (median of all 7 GC-MSs), expressed in % of present yields



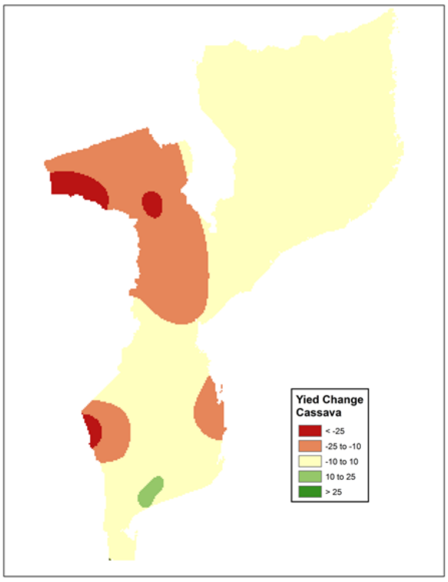
Projected future changes (2046–2065) for sorghum (median of all 7 GC-MSs), expressed in kg/ha



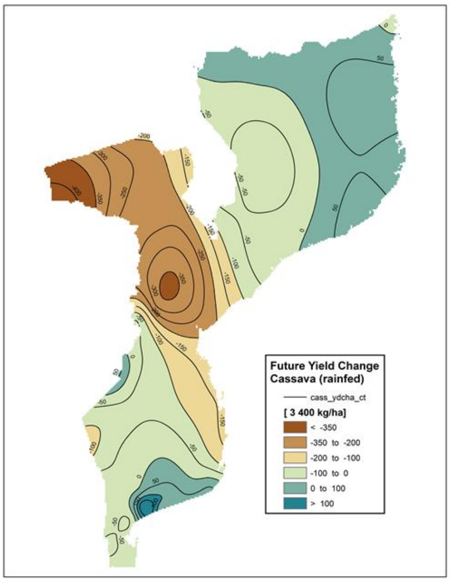
Projected future changes (2046–2065) for groundnut in % of present yields



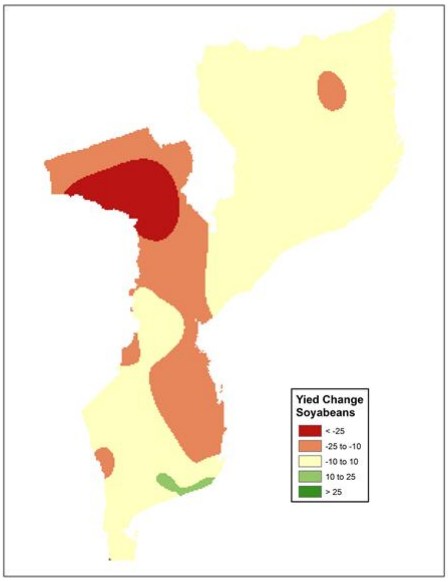
Projected future changes (2046–2065) for groundnut in kg/ha



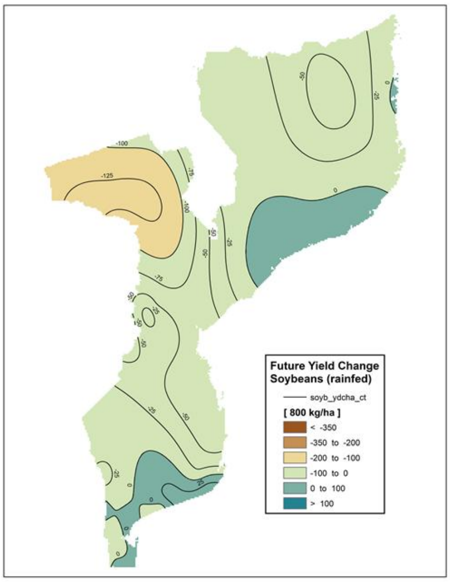
Projected future changes (2046–2065) for cassava in % of present yields



Projected future changes (2046–2065) for cassava in kg/ha



Projected future changes (2046–2065) of soybean yields in % of present yields



Projected future changes (2046–2065) for soybeans in kg/ha

Annex 7 shows the geographical distribution of projected changes in crop yields under rain-fed conditions expressed either as relative changes in present potential yields in % or as changes in actual crop yields in kg/ha. Results shown are for cotton, sorghum, groundnut, cassava and soybeans (for maize, see results in the main INGC Phase II report). The decrease in relative yields starts with a pocket in the west of Tete Province and then grows towards the coast and the south. Maize is the most affected crop, followed by soybeans, groundnut, cassava and sorghum, with cotton being the least affected crop.